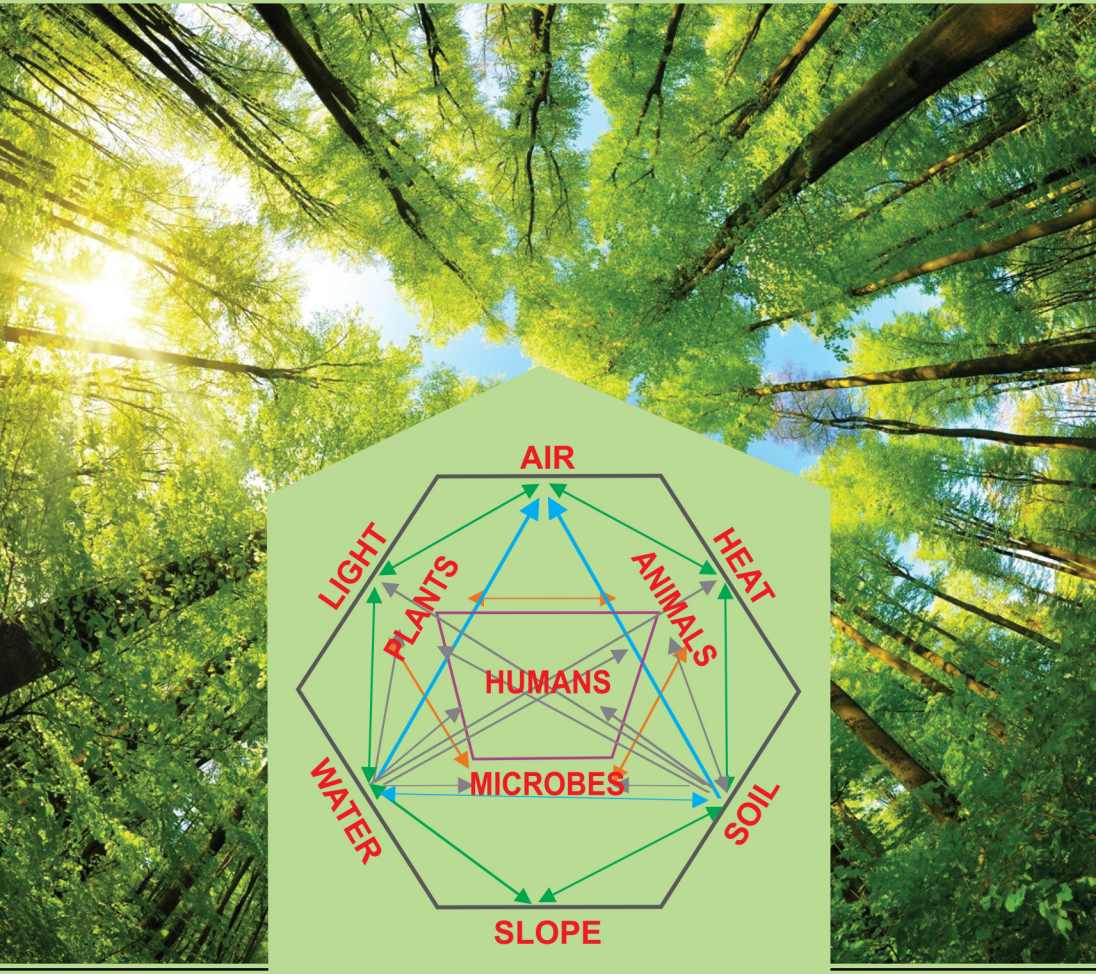
FUNDAMENTALS OF
ENVIRONMENT MANAGEMENT



INTER-RELATED & INTER-DEPENDENT ECO-SYSTEM

Dr. K. T. CHANDY S. J.

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Dr. K. T. Chandy S.J.

atmabooks@gmail.com

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Dedicated to

Saint Francis of Assissi

&

Pope Francis

Patron and Promoter of Better Environment

Introduction

The COP 26 UN Climate Change Conference hosted by the UK in partnership with Italy took place from 31st October to 12th November 2021 in the Scottish Event Campus (SEC) in Glasgow, UK. Out of the many things deliberated on environment COP 26 narrowed down to the following:

1. Leaders from over 120 countries pledged to halt and reverse deforestation by 2030,
2. A methane pledge, led by the US and the European Union, by which more than 100 countries agreed to cut emissions of the greenhouse gas by 2030,
3. More than 40 countries including major coal-users such as Poland, Vietnam and Chile, the biggest generators of CO2 emissions agreed to shift away from coal,
4. Nearly 500 global financial services firms agreed to align US$130 trillion which may be about 40 per cent of the world's financial assets with the goals set out in the Paris Agreement, including limiting global warming to 1.5 degree Celsius,
5. In a joint declaration, the US and China pledged to boost climate cooperation over the next decade. They agreed to take steps on a range of issues, including methane emissions, transition to clean energy and

decarburization and reiterated their commitment to keep the 1.5 degree Celsius goal alive,

6. More than 100 governments, cities, states and major car companies signed the Glasgow Declaration on Zero-Emission Cars and Vans to end the sale of internal combustion engines by 2035 in leading markets, and by 2040 worldwide,
7. At least 13 nations also committed to end the sale of fossil fuel powered heavy duty vehicles by 2040,
8. Ireland, France, Denmark and Costa Rica among others, as well as some sub-national governments, launched a first-of-its kind alliance, "Beyond Oil and Gas Alliance (BOGA)", to set an end date for national oil and gas exploration and extraction. *(Source: https://news.un.org/en/story/2021/11/1105792)*

India put forth two concrete achievable proposals: 1) create an International Solar Alliance and 2) A global coalition for Disaster Resilient Infrastructure.

This book on "Fundamentals of Environment Management" is an attempt to highlight some of the basic tenets of the environment management, enumerated as the "Commandments of the Nature" in the first chapter itself. It may be shocking to some of the readers to see the following key environmental imperatives echoed in different chapters of this book and are yet to find a place in the global environmental perspectives and discussions.

- Forests are the lungs of the earth playing key roles like carbon-oxygen exchange, biomass generation, maintaining steady precipitation, soil and water conservation and several other vital functions in the nature. Hence for the ecological balance at least 70%

of the global or each country's land area should be under perennial forest cover except the glacier areas. Deforestation is one of main causes of increase of carbon dioxide causing global warming.

- Any land which is at or above 33.3 per cent or 1:3 ratio in slope should be under perennial tree cover except the perennially snow covered areas. This aspect has not yet come into discussion in the UN Climate Change Conference: still to be realized.
- Hence every country should have a detailed survey of the topography of the surface area of its land marking clearly the areas above 33.3 per cent slope (the average critical angle of repose of the soil) that should be under perennial tree canopy cover or natural forests: Ideally canopy cover should be 100 percent.
- The present rate of top soil loss in the world and in India by erosion is highly destructive to the environment. The top soil loss in India amounts to an average of 6000 million tons per year. Waste land formation leading to desertification is a silent but steadily growing ecological menace in the world.
- The absolute ownership and the law of inheritance of the land prevalent in most of the countries are leading to endless land fragmentation and litigation for generations. That all agriculture lands should be permanently structured and "people should be given only the user's right and not absolute right" is yet to appear in UN agenda and discussion.
- Trees should be harvested according to the availability of harvestable trees and not according to the need or greed of the people. They should be harvested by "cut and lift method" rather than "cut and drag"

through forest land causing enormous soil erosion and destruction of flora and fauna. The UN is yet to discuss this aspect of the forest maintenance and utilization.

- The present ratio of world arable land used for animal husbandry and agriculture stands at 77 to 23 per cent is highly unsustainable: globally too much emphasis is being given to various types of meat and milk production compared to production of staple foods like cereals, pulses, oil seeds and vegetables. Members of the UN need to tackle this aspect of the land use.
- Very high animal population with very low productivity like that of in India and Africa is highly destructive to the eco-system; COP needs to think about it.
- Human body is the most intimate environment of a person/humanity; the present too commercialized form of food industry emphasizing only gustatory aspects rather than nutritional, is highly detrimental to humanity itself. Too much Commercialization of food creates imbalance in human nutrition and degrades humans both physically and mentally. Poor nutrition results in negative genetical changes causing both physical and mental defects, deformities and diseases which can become genetical and can be transmitted from generation to generation: the ratio of mentally and physically handicapped people in the world are on the increase.
- Chemical fertilizers may be needed for bringing out the full potential of high yielding varieties of crops. But they are to be applied only after applying organic manure at the rate of 1-3 kg per square meter or 10,000 to 30,000 kilograms per hectare per year. "Organic matter is the soul of the soil" and a soul-less soil cannot

utilize chemical fertilizers applied even according to agronomic recommendations.

- Control of crop pests and disease should be the responsibility of the government and not of the illiterate farmers alone; just as human and animal diseases need qualified doctors to diagnose and to treat, so too crop diseases and pests need specially trained plant pathologists and entomologists appointed at the government or private sector. At present we hear so much about spurious and adulterated allopathic medicines in the market; the problem of spurious and adulterated agro-chemicals is so rampant resulting into a spurt of many serious human diseases like cancer, mental and physical deformities among the world population.
- Well planned and implemented Watershed Management Programmes which are highly ecological and environmental should be implemented on a permanent and extensive way. Developing a permanent watershed management system is a one-time expense and the UN is yet to think about it. Most of the environment programmes become ineffective without watershed management practices.
- The "Recommended Land Use Pattern as per Slope of the Land" given in Table 1 in Chapter 1 of this book is part of the permanent land structuring in Watershed Management.
- The present global or certain country-wise density of human population is ecologically unsustainable. Perhaps the world can support only one-third of its present population: this is an open secret but the UN is yet to discuss.

- Presently the much trumped up annual tree plantation programme called "Vanamahotsava" in India is reduced to planting small seedlings or saplings every year in the same spot by different VIP's. People seldom realize that successful growing of trees to a viable stage requires nearly 8-10 years of concerted efforts from nursery to a growth of an average height of two to three meter.
- Check whether people are aware that "Only a healthy and vigorously growing, one meter high and one year old budded or grafted saplings for fruit trees and seedlings for forestry should be planted out into the field. On an average only fifty per cent of the plants raised in the nursery are worthy of planting out into the field. Poorly growing saplings or seedlings planted in the field will be a liability and their performance both in growth and production will be almost nil."
- Waste management is a global problem. Dumping of urban organic and inorganic solid and liquid wastes into the river systems is a major source of pollution that needs to be rectified in many countries. Israel is a role model in the use of domestic waste water for agriculture production. UN is yet to promote the slogan "Waste is Wealth" and to finance permanent waste management/ recycling systems in a serious way.
- The organic manure generation though costly is a necessity in an environmentally sound land use in agriculture. UN needs to focus its attention both in developing efficient technologies to process organic manure and in promoting the use of organic manure.
- Poverty is also a cause of Environmental degradation and destruction: population lacking sufficient basic amenities like food, clothes, housing and education up to college will be a dead weight on environment. "Slums

are embodiment of global housing crisis" and the percentage of slum dwellers in the world is expected to rise to the ratio of one to three by 2030-40. With such growth of slum dwellers environmental sustainability will be almost impossible.

Hope these issues will become subjects of discussions in the future COP Conferences. We are still at the discussion level. Environment Management is highly technical and at the implementational level many aspects of environment management needs different types of specific technical know-hows. For the benefit of those who are interested in specific technical know-hows on various aspects of land and natural resource management, a list of 727 technical papers available freely on-line are listed in Appendix- Chapter 17.

I am grateful to hundreds of people spread all over India who were part of many environment management programmes held at the grass root to very high academic level. I am also grateful, to Fr. Dr. E. P. Mathew, Provincial of Kerala Jesuit Province, and his administrative team, for encouraging me and providing me the infra-structure and support for writing this book. I also acknowledge internet sources for a good amount information included into this book. My gratitude also to Mr & Mrs K. T. Thomas for their valuable support.

Dr. K.T. Chandy S.J.
Rtd. Prof. Environment and Natural Resource Management
XIM, Bhubaneswar, Odisha

CONTENTS

Chapter-1

World Environmental Days and Commandments of Eco-system

(There are Seventeen Global Environmental Days which are related to Commandments of the Nature. A Commandment means unquestionable divine order; it implies power of commanding and something commanded; whereas natural law means rules of right and wrong implicit in the nature itself. They merge with each other when divine is natural and the natural is divine and hence immutable or if violated serious consequences will follow: Peace and Harmony in the Nature will be disrupted)

Important Environmental Days Observed World Wide are the following. It is worth studying all of them in brief.

1. February 2 (World Wetland Day):

Wetlands are a very important part of our biodiversity and it is essential to see that they are well protected. The Convention on Wetlands of International Importance was held at Ramsar in Iran and the World Wetland Day treaty was signed on Feb 2, 1971. Wetlands are highly productive and biologically diverse systems that enhance water quality, control erosion, maintain stream flows, sequester carbon, and provide a home to at least one third of all threatened and endangered species. Wetlands are important because they improve water quality and provide wild life habitat. Currently there are 2414 Wetlands of

International Importance under Ramsar treaty spreading over 254,540,512 ha of lands across the globe and in India there are 39 of them.

2. February 28 (National Science Day):

National Science Day is celebrated in India on 28 February each year to mark the discovery of the Raman-effect by Indian physicist Sir C. V. Raman on 28 February 1928. In 1986, the National Council for Science and Technology Communication (NCSTC) requested the Government of India to designate February 28 as National Science Day. The scientists felt it was necessary to highlight the role of science in the protection of the environment. Environment management is both a science and an art.

3. March 21 (World Forestry Day):

By the resolution of the United Nations General Assembly on November 28, 2012 the International Day of Forests was established to be held on 21st of March. Forests are the lungs of the earth: it maintains the CO2 and O2 ratio in the atmosphere at the optimum level. Globally each year an estimated area of 13 million hectares of forests are lost. As these forests vanish, so too about 80% of the plants and animal species of terrestrial biodiversity get extinct; deforestation reduces the annual rainfall and water holding capacity of the soil, resulting in the drying up of most of the springs, streams and other water sources. Deforestation causes massive top soil erosion causing soil productivity loss; most importantly, forests play a critical role in climate change; deforestation results in 12-18 percent of the world's carbon emissions, almost equal to all the CO2 from the global transport sector. Today, forests cover more than 30% of the world's land and contain more than 60,000 tree species, many as of yet unidentified. Forests provide food,

fiber, water and medicines for approximately 1.6 billion of the world's poorest people, including indigenous peoples with unique cultures.

4. March 22 (World Water Day):

World water day was first formally proposed in Agenda 21 of the 1992 United Nations Conference on Environment and Development in Rio de Janeiro. The decision to celebrate this day has been taken recently as drinking water sources are fast depleting. The world must wake up to the problem and begin conserving it. World Water Day is an annual United Nations observance day held on 22 March that highlights the importance of fresh water. The day is used to advocate for the sustainable management of freshwater resources.

5. March 23 (World Meteorological Day):

Everyone has to be reminded that weather is an integral part of the environment. World Meteorological Day was established in 1961 to commemorate the World Meteorological Organization creation on 23 March, 1950. This organization announces a slogan for World Meteorology Day every year, and this day is celebrated in all member countries.

6. April 7 (World Health Day):

The World Health Organization (WHO) was constituted on this day in 1948. In the changing environment around us health is becoming an important issue. World Health Day is a global health awareness day celebrated every year on April 7, under the sponsorship of the World Health Organization, as well as other related organizations.

7. April 18 (World Heritage Day):

Established in 1972, it is the only international conservation instrument that explicitly links nature and culture, recognizing the complex interactions between mankind and the environment. Environment includes not just the natural surroundings but also the manmade ones.

8. April 22 (Earth Day):

In 1970 a group of people in the United States of America got together to draw the attention of the world to the problems being caused to the earth due to modernization. Since then this day has been celebrated all over the world as Earth Day an annual event on April 22 to demonstrate support for environmental protection. First held on April 22, 1970, it now includes a wide range of events coordinated globally about a billion people in more than 193 countries.

9. May 31 (Anti Tobacco Day):

The Member States of the WHO created World No-Tobacco Day in 1987 to draw global attention to the tobacco epidemic and the preventable death and disease it causes. The day is further intended to draw attention to the widespread prevalence of tobacco use and to negative health effects. Currently it is estimated that more than 8 million tobacco related deaths occur each year worldwide, including 1.2 million are the result of non-smokers being exposed to second-hand smoke.

10. June 5 (World Environment Day):

World Environment Day was established in 1972 by the United Nations at the Stockholm Conference on the Human Environment that resulted from discussions on the integration of human interactions and the environment. Two years later, in 1974 the first WED was held with the

theme "Only One Earth". Even though WED celebrations have been held annually since 1974, in 1987 the idea for rotating the centre of these activities through selecting different host countries began.

11. July 11 (World Population Day):

The event was established by the Governing Council of the United Nations Development Programme in 1989. It was inspired by the public interest in Five Billion Day on July 11, 1987, the approximate date on which the world's population reached five billion people. Population has to be given special attention, as it is an ever-increasing problem especially in India.

12. September 16 (World Ozone Day):

In 1994, the United Nations General Assembly proclaimed 16th September, the International Day for the Preservation of the Ozone Layer, commemorating the date of the signing, in 1987, of the Montreal Protocol on Substances that Deplete the Ozone Layer.

13. September 28 (Green Consumer Day):

Green consumption is closely related to the notions of sustainable development or sustainable consumer behaviour. It is a form of *consumption* that is compatible with the safeguard of the environment for the present and for the next generations. It is a concept which ascribes to consumers responsibility or co-responsibility for addressing environmental problems through the adoption of environmentally friendly behaviors, such as the use of organic products, clean and renewable energy and the research of goods produced by companies with zero, or almost zero, impact (zero waste, zero-emissions vehicle, zero-energy building, etc.) The problems of

consumerism and its impact on the environment is an area of major concern in today's world. Awareness building on the importance of recycling, reusing, reducing should be taken up seriously.

14. October 3 (World Habitat Day):

In 1985 the United Nations designated the first Monday of October every year as World Habitat Day. The idea is to reflect on the state of our towns and cities and the basic right of all to adequate shelter. It is also intended to remind the world of its collective responsibility for the future of the human habitat. The earth is the habitat of not only human beings but also all living creatures. Increasing human activities is threatening the habitat of other living things.

15. October 1-7 (World Wildlife Week):

Celebrate this week by building awareness on the importance of preservation of our wildlife. On 20 December 2013, at its 68th session, the United Nations General Assembly, in its resolution UN 68/205, decided to proclaim 3 March, the international day of the adoption of the Convention on Wild Life.

16. October 4 (World Animal Welfare Day):

The welfare of animals has to be looked into and given due importance. World Animal Day is an international day of action for animal rights and welfare celebrated annually on October 4, the feast day of Francis of Assisi, the patron saint of animals.

17. October 13 (International Day for Natural Disaster Reduction):

The International Day for Disaster Reduction is an international day that encourages every citizen and

government to take part in building more disaster-resilient communities and nations. Due to a change in the environment there has been an increase in the number of natural disasters. Efforts have to be taken to reduce these disasters.

General Comment

After scanning through many of the world level declarations and conventions someone remarked, "Declarations are galore, but meager are the achievements", because the world bodies are still to understand and follow the laws or commandments of our earth-eco-system. The word commandment refers to Yahweh's (Israel's God) promise of the 'land flowing with milk and honey' to the people of Israel depending on their 'faithfulness to His commandments'. In the present times also the earth will be a suitable habitat, only when we follow the commandments or laws of the Nature: our earth-eco-system. People all over the world have to use the natural resources to make a living and to achieve developments in all spheres of their life which is a struggle as old as humanity itself. In that process some are greedy to amass as much as possible even at the expense of others' experience of dire scarcity: abundance of the very few and the dire scarcity of basic requirements for life for vast majority of people. The same theme is running through the Indian mythologies like Mahabharata and Ramayana; the history of mankind is riddled with endless struggles for possession of land and its resources. Same struggle is going on even now in different parts of the world. China's open and subtle manoeuvres both in the land in the sea, the dispute between India and Pakistan over Kashmere, the Israel-Palestine struggle for land, the dispute between the countries born out of the former Yugoslavia, the massive migration of people from Asian-African countries to the

European countries are all instances of people's struggle for land. In India people are craving for land as their main source of livelihood. Land for people in many countries is not only an economic necessity but also an essential cultural and social identity. The world refugee problem is a repetition of the same old story of people craving for a habitat. All living beings originate from the earth-eco-system, develop and complete their life cycle to pass on the same eco-system to the next generation. In the process the earth resources like water and all the living beings surviving in water, topsoil and its fertility, crops and other plants, domestic and wild animals are slowly disappearing: already thousands of species have disappeared; and here comes the question of sustainability of our earth-eco-system and its natural resources.

Trade for wealth accumulation is the hallmark of the modern human society; but the way trade is carried out now at the local, national or global level is certainly cutting into all aspects of environmental sustainability. Arthur Dunkel, the director General of GATT, in his plenary presentation to the UN conference on Environment and Development, Rio De Janeiro, June 11, 1992 affirmed, "Trade is not an end in itself; rather it is a means to an end. The end is environmentally sustainable economic development." (*"Environment and Trade as Partners in Sustainable Development"*, The American Journal of International Law, Vol. 86, p 728). It is not the sustainability of development that is foremost among all the issues now facing the humanity but the sustainability of the earth itself. To maintain environmental sustainability and to attain sustainable development, the nature of the environment implies certain immutable laws or commandments which are binding on every human being. The purpose of this chapter is to highlight those immutable laws for maintaining

the sustainability of all the life supporting components of our earth-eco-system itself.

Modern Environmental Awareness

Till recently every one took for granted whatever is in the nature and people all over the world used them freely and lavishly to the extent of the extinction of many of plant and animal species. Half of the topsoil of our planet has been lost in the last 150 years. In addition to erosion, soil quality is affected by various aspects of agriculture and animal husbandry land uses and uncontrolled urbanization. These impacts include compaction, loss of soil structure, nutrient degradation, and soil salinity, effects of soil erosion go beyond the loss of fertile land. Above all the organic matter content, the soul of the soil, is steadily decreasing. Today we know that most of the environmental problems are man-made due to over-exploitation and mismanagement of natural resources including humans themselves. The earth-eco-system is only one of the planets of the solar system and as far as we know earth is the only planet with the type of life we now know. We also know that all forms of life on earth depend on the sun as the sole source of energy. The sunlight consists of light particles or photons which are compared to sperms from the father fertilizing the mother earth to produce all the living beings on earth. Some of the ancient religious observations and religious rituals and observances signify earth as mother and sun as father. The same may be reflected in the Linga and Yoni worship in some cultures. In short our eco-system is a continuum of "sun-soil-slope-water-air-light-heat-microbes-plants-animals and humans" as depicted in the cover page of this book. The light and heat required for the earth and all in it comes from the sun; hence sun too is part of our earth's eco-system or the other way around as depicted in Fig 1.

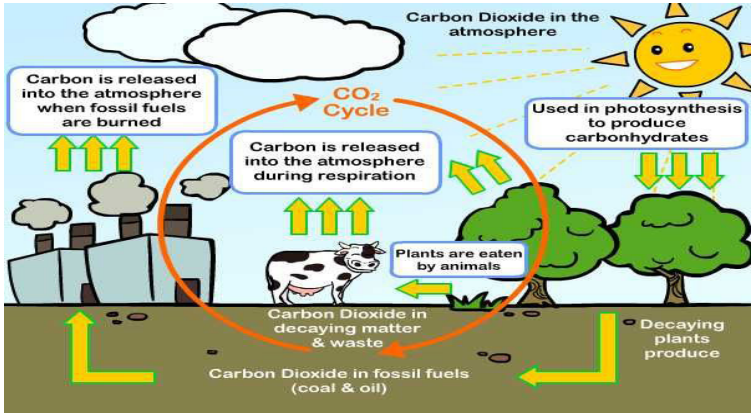


Figure 1 Sun and Earth-Eco-System Continuum

Light and Dark Reactions

During the infusion of sun energy in the form of light into the plants to produce carbohydrates the basic form of chemical energy (carbohydrate) used by all the living beings. We seldom realize the mystery of photosynthesis that is taking place in the chlorophyll part of the green leaves of the plants in converting water and corbondioxide into carbohydrate and oxygen trapping solar energy during the day time (photosynthesis) and during night the reverse reaction (dark reaction) takes place using up carbohydrate and oxygen releasing carbon dioxide and water vapor into the atmosphere, thus maintaining the optimum ratio between oxygen and carbon dioxide in the atmosphere as shown in the two equations in Figure 2.

Day time: $6CO_2 + 6H_2O + \text{Sunlight (684kcal)} \rightarrow C_6H_{12}O_6 + 6O_2$ **(1)**

Night time: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy (684kcal)}$ **(2)**

Fig 2. Photosynthesis (1) Light reaction and (2) Dark reaction

Another key point in the **eco-system** is that all the nonliving components are essential supportive factors for the survival of any living being whether microbes, plants, animals or humans. A third key factor is that all the living beings derive their additional elemental nourishments from all the five nonliving components especially from the soil, water, air, light and heat to grow, develop and fructify; but finally they all die and merge into the soil and ultimately back into the five elements. In other words the **same elements are cycled and recycled again and again between various components in the Nature or eco-system. Chemically everything in this world may be classified into two: inorganic matter and organic matter.** In the nature both inorganic and organic matter cycles are taking place. Every element cycles through various components of the eco-system. Given here are in Fig 3 the cycles of carbon-dioxide and nitrogen as examples of cycling and recycling

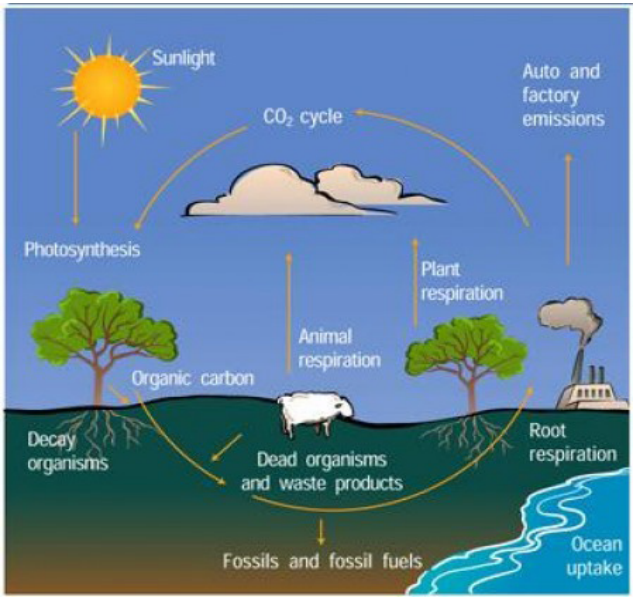


Fig 3: Carbon Dioxide Cycle in the Nature

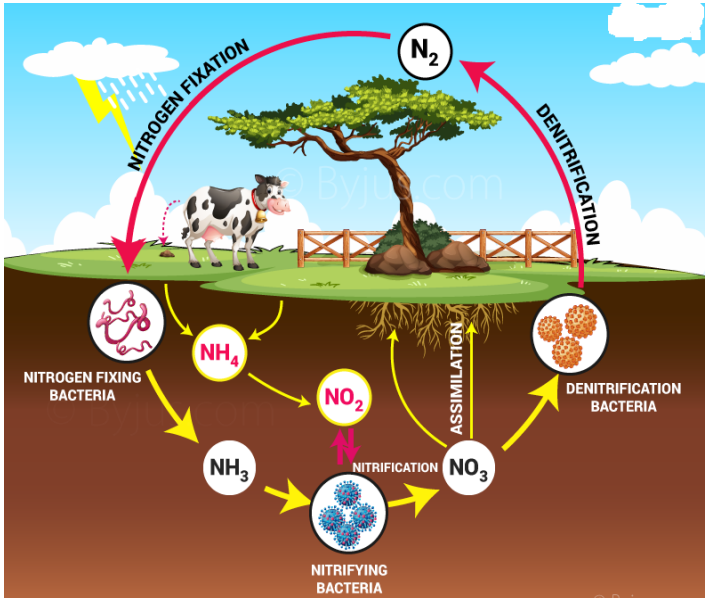


Fig 4: Nitrogen Cycle in the Nature
(NB.The students may study the pathways of the cycles of other elements and compounds)

It is through these inorganic and organic matter cycles that everything in this world is having its origin, growth, development, decaying and decomposition. Earth is a womb and a tomb for everything living and even for the non-living. A continuous cycle of construction, destruction and again construction is taking place in the nature. In a Hindu sense a continuous "**Cycles of Reincarnations"** and in a Christian sense a continuous cycles of **"Deaths and Resurrections"** are taking place in the nature. Something or someone dies and decomposes so that another one rises up. In other words whatever is happening in the nature is in a cyclic process; this process is also progressive. Generations of components are in cyclic process while between generations of components

a progressive movement takes place. For the stability and progress of the nature, our eco-system these two cyclic and progressive processes should be maintained. Hence it is a process of evolutionary and teleological or moving towards a goal which may be now unknown to us humans. **Hence we can say that the whole world is in an inorganic, organic, progressive, teleological, evolutionary process in which everything even the smallest sub-atomic particles have a role to play and we humans are invested with the inherent duty of preserving and facilitating the same process for his own well being and all other living beings. In other words Humans have the duty to preserve the sustainability of the eco-system of our mother earth.**

People all over the world have become very conscious of the problems related to environmental degradation and it is high time to realize that there are some unwritten "Laws of the Nature" based on which environmental preservation and development programmes have to be planned and implemented. All social and religious rules and regulations of ancient civilizations including the Ten Commandments help us to establish peace and justice between humans. But the Commandments of Nature help us to establish peace and justice, not only between humans but also between humans and Nature. An attempt is made in this volume to enumerate and define briefly the "Commandments or Laws of Nature" that govern the ecological balance. Much more than the Judeo-Christian Ten Commandments, the Commandments of Nature need a lot of study, discussion and debate to acquire a deeper understanding of the fragile nature of our eco-system.

As we have already seen earth is our immediate eco-system while the solar system is our proximate eco-system and the Milky Way is our remote eco-system and

the whole universe is our remotest eco-system. The earth itself is so big to study it as an eco-system and yet we have to take it as a unit in our study on our ecosystem because anything happens anywhere on the earth including in the atmosphere affects all other parts of the earth as well as all the components existing in it whether living or non-living. As already mentioned the major components of the eco-system are: sun light, soil, slope, water, air, light, heat, microbes, plants, animals and humans as shown on the cover page and also in Fig 1 and Fig 2 in this chapter. There are six nonliving components and four living components. Under each of these components we have sub and sub-sub classes of components, the study of which is necessary to acquire sufficient knowledge about the earth-eco-system.

For example the soil consists of all chemical elements in solid form and is the result of millions of years of weathering of rocks which were formed by the cooling of solar gases, first into liquid and then into solid rocks. Later by the slow weathering of the rocks soil was formed on the crust of the earth. There are scientists studying the soil all their lives unraveling the mysteries of soil in relation to all science subjects.

Though slope of the land is not a substance like soil and water it does have a strong influence on all other components of the ecosystem. Both soil and water cannot remain stationary even on a one percent slope. Height and slope go together in the nature; as the height increases the slope factor also increases. As height increases the density/pressure of air becomes less and less; so too the temperature become less and less. When soil and water are affected by the degree of slope the microbes and plants are also affected which in turn will affect the animals and humans. **However, even now most people in the world are unaware of the**

influence of the slope on the eco-system. Neither at the international nor national declarations and directives on environment management, the slope factor does appear. Slope is as dynamic as the energy residing/inherent in the soil, water, air, light, heat and all other living components. When a slope causes, landslides, avalanches, water rush, fall of trees, injury and death to animals and human, **is it not acting like a living being?** Wherever energy is active even the so called nonliving beings become and act like a living being. There is so much of life or energy even in an atom which is very much active at the subatomic level as we all now know.

Water is a combination of Hydrogen and Oxygen (H_2O) in a specific ratio and can exist on the earth in three stages: in solid, liquid and gaseous forms depending on the temperature. The study of molecular structure of a water molecule and its properties evokes a sense of wonder in any one. Water is indeed a wonderful substance in the nature and an essential component in every living being. At the same time the fury and calmness of water in the sea is phenomenal. As such, all living beings need water as an essential component of their body composition.

The air is a mixture of several elements in gaseous form. The air circulation around the earth is a natural phenomenon yet when we study about it evokes a sense of wonder.

The components of light and heat we normally receive from the sun which is external to earth. However these two components are always with the earth, and they are the integral part of our mother-earth eco-system. That is the reason why we say the solar system is our proximate eco-system and that is why from ancient times sun is considered as a god to be worshiped.

The last four components microbes, plants, animals and humans are living and biological in nature and function. As we move from microbes to humans the dependency syndrome of each of the living components on all other previous components increases. In other words the microbes are depending on soil, slope, water, air, light and heat, while plants depend on soil, water, air, light, heat and microbes. Similarly the animals depend on all the six nonliving components as well as microbes and plants. Finally humans, though they are the last to appear on the earth depend not only on all the six nonliving components but also on the microbes, plants and animals for their existence and development: **humans are the most dependent being on earth.** At the same time, compared to all other living beings, **their ability to control and manipulate the same components is also at maximum level**. Thus though **man is the master and manager of all the components in the Nature yet he is the most vulnerable component in the same Nature.** If anything happens to any of the other nine components, his life will be affected drastically or even the human life will be impossible. Similarly if anything happens to the plant kingdom then all the animals and humans will be affected. In the same way if the soil or water in our eco-system is eliminated by the slope then the plant life will be affected and consequently both animal and human life will be affected. In other words the **equilibrium of our eco-system is governed by certain laws of Nature which are qualitative and quantitative in nature**. We can name them as **"Laws or commandments of Nature".**

Laws or Commandments of Nature

The **commandments or Laws of Nature** arise mainly out of the **mutual inter-connections and inter-dependence** between these six **nonliving components**

(soil, slope, water, air, light and heat) and on each of the four **living components** such as microbes, plants, animals and humans. Analyzing the interdependence between all the ten components we can derive the "Commandments or Laws of Nature". For the present we have identified the following **Natural Laws or commandments of nature. The numbering order of the laws does not mean the order of priority or importance: one and same is our earth-eco-system for everyone and its laws are only the different aspects of the same management.**

First Law: a) Law of proportion between the areas of oceans and lands. The actual area proportion between oceans and land is 71:29; but we may consider this ratio as 70:30 for convenience in further computations. b) Preserve also all the inland water bodies in the form of ponds, lakes, marshy lands, mangroves, rivers, streams and springs and protect them.

The seas and the land area form the base for all the nonliving and living things on the earth and hence we may consider their proportion as 70:30 in percentage. Besides sea there are other water bodies like lakes, reservoirs, ponds, marshy lands, swamps, mangroves, river systems, streams, springs etc. on the land area, which should not be disturbed but should be kept intact. In this connection the solidified water bodies like, glaciers, snow covered mountains and Polar Regions also should be considered as water bodies. All these water bodies along with sea may make up around 75% of the surface area of the earth. All these water bodies should be preserved and protected to maintain an ecological balance. Man can influence a lot on the inland water bodies both positively or negatively. Hence we Should: followed by

1. Preserve all the natural water bodies and if possible create more water bodies wherever possible on the marshy

and low lying lands. Even in a human, animal or plant body on an average 70% of volume consists of water. To main this average proportion of water in a living body aquatic animals are in water; but terrestrial humans and animals need to drink water frequently and also keep themselves within a range of humidity between 40-60 per cent. To maintain this level of humidity, nature maintains 70% of its area as oceans, besides many inland water bodies mentioned as above and a certain percentage of area under perennial forest cover especially the hilly areas.

2. Create as many water bodies as possible on the hills and mountain regions by collecting rain and surface runoff water or water from streams originating from higher slopes of the mountains by diversion channels into suitable storage structures natural or artificially created. The water thus stored will sink into the mountain soil and will appear at the lower ranges of the same mountains in the form of numerous springs of perennial nature. Lakes and bigger water bodies on the hilly areas will promote rise of underground water storage which may appear in the form of artesian wells as seen in the plains below the Nainital-Bhavali-Naukuchiatal-Sat-tal areas where there are many natural lakes. These lakes being at the higher regions will allow to sink part of the water collected during the rainy season into the soil of the plains where the same water is drawn out from artesian wells. The same will promote forest growth in the hills and mountains which in turn promote wild life. **Hills and mountains covered with perennial natural forests are the living storages of water**. Some may *ask* "How can a forest-covered mountainous area become huge storage of water?" Though it takes a long explanation to answer this short question let me try to satisfy the curiosity of the possible readers of this volume after explaining what we can do.

3. A protective cover of suitable vegetation should be maintained around all the inland water bodies to minimize erosion of soil and other debris coming into them. This is also applicable to all the rivers and streams. The width of the protective cover on both sides of the rivers and streams should be proportionate to the width of the river or stream in the plains while in the hills it should be as much or as wide as possible. Such protective vegetation should never be disturbed under any circumstance. Control of soil erosion into the water bodies on the land is one of the most crucial aspects of environmental protection.

4. Ensure a perennial forest covering on all the land at and above 33.3 per cent (1 rise to 3 run) slope at which most soil types have maximum stability and also the origin of all the natural springs and water sprouts which sustains all the small and big streams which in turn maintains the small and big rivers. A forest system also maintains high humidity facilitating higher rainfall.

Estimation of water in a forest system: That a **forest system is a very-high-volume water storage in the nature** can be proved by simple calculations**.** A forest system consists of soil volume, vegetative volume and air volume. For the time being moving volumes of animals and humans in the forest system are not considered. Both air volume and soil volumes are limitless in the sense the height of the air volume can be the whole atmospheric height and the depth of the soil volume theoretically can be to any depth up to the centre of the earth. But we can limit the height of the air volume up to 10 km and the depth of the soil to 10 meters (33 ft) and the area of a forest as 100 hectares.

Now we must recall that air contains moisture in the form of humidity normally varying from 50 to 90 per cent over a perennial forest system in the tropical region; the

plant and animal body contains water on average around 70% and the soil porosity varies from 50 to 75 per cent and it can contain water equivalent to its porosity or percentage of it. But if the forest area contains streams, rivers or marshy lands or lakes the water content in the soil volume will be more. Here our intention is to give an idea of the quantity of water contained in a forest system. For convenience we can estimate the water content in all the three volume components of a 100 hectare of any forest area and then multiply it with the total area of the forest.

We all have seen how much water comes down from the atmosphere during the rain; we can also estimate the amount of water containing in the bio-mass of plant system; similarly we also can sample out soil from various parts of the forest area and estimate the amount of water stored in that forest soil. At the end of the estimation we will be surprised to note the total amount of moisture content present in the forest eco-system consists of atmosphere, forest plants and soil. Then we will understand what it means to say that **a perennial forest system of at least 90% canopy cover is a reservoir of water.** The water content in the forest is proportionate to the forest cover as shown in the following example.

In a hundred hectare forest system there will be thousands of cubic meters of water in storage. Let us make it clear through an example. The reader is cautioned not to take the values of the following calculations as absolute values. They are only estimates and indicative of the ideas I want to express. People usually do not realize the water holding capacity of the natural forest systems and the essentialities of a forest system in an eco-system as well as in our life. Let us go through a hypothetical example of estimating the water content of a 100 hectares of perennial

forest system consists of forests, air volume up to 10 km and the soil volume up to the depth of 10 metre (33.3 feet).

Let the area of the perennial forest system be 100 hectares (1000x1000 meters/10,000 sq. metre). So the area of the air volume will be the same. (The numbers 100 is taken for easy calculation). Let us fix the height of the air volume or atmosphere under consideration as 10 kilometers (10000 meters or 33000 ft). That means the air volume above the forest is a 1x1x10 =10 cubic kilometer. It will amount to 1000x1000x10,000 =10,000,000,000 cubic meter or ten billion cubic meter air volume. Let us assume the average percentage of humidity as 50 percent at an average of 30 degree Celsius. (Now scientists have estimated that 17.3 gm or cc of water is required on an average to make one cubic meter of air volume at around 20 degree Celsius 100% saturated. From this we can also estimate the increase in the quantity of water in gram or cubic centimeter for an increase in one degree centigrade which amounts to 0.865 cubic centimeter (17.3/20=0.865). Then at 30 degree centigrade the amount of water required for the relative humidity to be 100% will be 25.95 or 26 gm or cc (0.865x30=25.95). For the increase of every degree of temperature there is on an average an increase of 5% increase in the humidity. These findings become handy to estimate the water content an air volume at a particular temperature or at specific percentage of humidity) Then the total amount of water required to make the air volume of 10,000,000,000 cubic metre will be 26 x 10,000,000,000 = 260,000,000,000 (260 billion cubic cc) which is equal to 260,000,000 (260 million) liters (1000 cb cc =1 liter) or 260,000 cub meter (1,000 litres = 1 cub meter) at 100% humidity. Hence the amount of water estimated at 50% humidity amounts to be 130,000 cub meter (260,000/2). Therefore the volume of water in the air volume above 100

hectare forest area at 30 degree Celsius and at 50% relative humidity is **estimated to be 130,000 cub meter or tone**, since one cubic meter water weigh one tone.

Next let us estimate the volume of the trees and plants existing in 100 hectare natural forest area. For this, take a few sample locations of 100 square meter (10x10 metre) area from the forest area. Cut all the vegetations in each location and find the fresh weight of the total biomass in each location. Then find out the average bio-mass weight. Let us assume it to be 10 tones for the sake of easy calculation. Assume the percentage of water content in the fresh weight of the biomass as 70 per cent. So each 100 square meter area will have 7 tones or 7 cubic meter of water (one cubic metre of water weigh one tone). Now one hectare is 10,000 square meters. Therefore 100 hectare will be 10,000 x 100 = 1,000,000 sq meter. At the rate of 7 tones of water per 100 square metre, in 1,000,000 sq meter or 100 hectare forest volume will have 1,000,000x7/100 = 70,000 cubic meter or **70,000 tones of water**.

Next let us estimate the water content in the **soil system of the forest**. Let us assume that we can utilize the water sources up to a depth of 10 meters (33ft) in the forest system and let us also assume that the average moisture content in the soil is 50 per cent. The total soil volume of the 100 hectare forest area under consideration is 1000 x 1000 x 10 = 10,000,000 cubic meters. Hence the total volume of water in the forest-soil-system will be 5,000,000 cubic meters (10,000,000/2) or **5,000,000 tones of water.**

Thus the total estimated amount of water present in a 100 hectare forest system will be 130,000 + 70,000 + 5,000,000 = 5,200,000 cubic meters. One cub metre is one ton. To contain this amount of water we need a reservoir or pond of 1000x100x52 metre size. This is quite

a lot of water. This is an awareness method of estimating the quantity of water present in an eco-system which has three volume components as we have seen and estimated their possible water volumes. There can be other better methods of estimating the water volumes in the eco-system. However isn't it amazing that a 100 hectare of perennial forest area can store on an average (50% capacity) such an amount of water? A mountain range may be thousands of hectares if not tens of thousands or lakhs. We can certainly imagine the estimated amount of water in such a huge area and its impact on the whole mountainous eco-system. It will give rise to many springs which becomes the source of water for several streams temporary or perennial. The main point is that **the forest lands are huge reservoirs of water which will give rise to numerous springs which will feed the streams and rivers of the country.** In conclusion we can say that a volume **EARTH-FOREST-AIR-VOLUME-ECO-SYSTEM is primarily a WATER SYSTEM.** But if the above mentioned 100 hectare land is devoid of forest, there may not be any water at all in soil and atmosphere in the form of humidity resulting in the drying up of all the streams and rivers originating from that area.

UN/FAO recommended to all the member countries to maintain 31% of their land area under perennial forest instead of all the hilly areas at and above 33.3% slope. Ever since forests have been reduced to 31% or less than that in most of the countries without reference to the slope of the land, our mother earth has been experiencing high soil erosion from the hills resulting in the death of numerous springs and water sprouts, drying up of streams and rivers, slow desertification in the plains and acute water scarcity for plants, animals and humans. Most of the countries in the world have actual perennial forest area only less than 20 percent. The actual forest cover in India is about 22.9

per cent though our forest policy recommends forest cover of 66.6% in the hilly areas and 33.3% in the plain areas. In the Indian plain areas practically there is no forest. The governments and people of most countries seems not knowing the consequences of accelerated deforestation resulting in accelerated soil erosion which in Indian continent alone amounts to 6000 million tons per year. All the springs and streams which were feeding the rivers have dried up due to high silting and people are struggling for water both domestic and agricultural use; the domestic animals are dying of thirst; while the wild animals are coming out of their forest-habitats in search of water and food into the human habitat areas. Perhaps the only way to regenerate numerous dried up springs and water sprouts to solve the problem of water is to go for massive reforestation of all the hills and mountainous areas at least at and above 33.3% slopes in a country. **People have to realize that the perennial forest areas in hills and mountains are huge reservoirs of water.** We must also remember that the water stored in mountainous areas in the form of forests and forest soil would have high potential energy stored up and hence it comes out at the base of the mountains in the form of numerous springs and water sprouts. If there is no forest cover in the mountains then no water can be stored up in the mountainous regions and consequently there will be no springs and water sprouts at the base of the mountains resulting in severe droughts, extensive crop failure and famine for both animals and humans. **In conclusion it should be understood by everyone that the whole earth-eco-system with all the hilly areas, at least at and above 33.3% slope, under perennial forest cover is a water-storage-system on the land; this leads to the second law of nature.**

Second Law: On the land, the proportion of perennial forest area to the non-forest area for regular human use

also, should be at the ratio of 70:30 on the globe as a whole or even in a country. This 70% forest cover should begin with hilly areas: first all slopes at and above 33.3% slope and then to the lower slopes and if need be to the plains to make up to the 70 per cent target forest cover on the land area.

The second law talks about the ratio of the perennial forests to the non-forest areas on the surface of the land. In the previous law we mentioned about forests as reservoirs of water. But in the second commandment **forests are considered as lungs of the nature**. **Forests absorb the carbon-dioxide and release the life sustaining oxygen much needed for all the living beings including the vegetation during the day and at night the reverse reaction takes place as mentioned already in the introduction. For the benefit of the readers the equations are presented again as follows (Fig 4). As we all know lungs in animals are the main organs that carry out the exchange of oxygen with carbon dioxide and vice verse. The forests or any green leaved plants do the same and this process is very essential for the maintenance of oxygen and carbon dioxide ratio in the atmosphere.**

Day time: $6CO_2 + 6H_2O + \text{Sunlight (684 kcal)} \rightarrow C_6H_{12}O_6 + 6O_2$ **(1)**

Night time: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy (684 kcal)}$ **(2)**

Fig 5. Photosynthesis (1) Light reaction and (2) Dark reaction

Forests are also treated as a biological store house in the nature. Forests are home for thousands of flora and fauna specific and general to any region. Forests are also needed

for stabilizing climate variations which has become very crucial these days. **Due to all these reasons just like nature has determined the area cover of the water (sea) on the surface of the earth as 70 per cent, so also on the land, forests should occupy 70 per cent area including all the area above 33.3% slope to maintain ecological balance of all flora and fauna including humans.**

There was a time the whole land mass was covered with forests in which both people and animals all lived and depended on forests for their necessities. Gradually humans began clearing the forest for settled cultivation, habitation, urbanization, institutionalization and industrialization. Today, as already mentioned, most of the countries in the world have forest area much less than the optimal. Almost all the hilly areas have been cleared for timber industries. People are ignorant about the required proportion of forest area to the non-forest area as 70 to 30 per cent. The slogan "land for the landless" is heard everywhere resoundingly and it appeals to everybody as really true and just. But the negative environmental consequence of this political and social thrust cannot be estimated (inestimable). Land area is limited yet the ratio between forest and non-forest area even in the limited land mass has to be maintained at 70:30 per cent for maintaining a healthy environment to humans and animals and for sustainability of the earth-eco-system.

The above mentioned 70:30 ratio is the fundamental underlying principle in the preservation of our environment and land-eco-system which every one especially planners and policy makers of the land and natural resource management programmes should be aware off. It will not be an exaggeration to say that no one should go against this law or commandment. Further it should be remembered that it is suicidal to go against this law. The 30% non forest area is

meant for various types of human activities like habitation and livelihood and functional engagements. If the whole land is flat but is a desert or waste land or uncultivable land then it cannot be used for cultivation but may be used for any other non-agricultural purposes like quarrying, mineral extraction, buildings or scarce forestation. All efforts should be put in to reforest such eroded areas with xerophytic plants that can grow even in the desertic waste lands; we have to choose the type of trees that will grow in semi-desert areas or waste lands.

Another subsidiary principle in the environment management is to reforest all the uncultivated, barren or rocky land in the plains. The desert or semi-desert areas also should be reforested though it takes a lot of time, effort and money. Remember all the present day deserts were forest areas once upon a time. They can be reforested with specially selected desertic vegetation. Even the cities and residential areas can be forested up to 50 per cent of the area. Tree covered residential areas are the most suitable human habitation one can think off. Environmentally sound residential areas will have well constructed residences with well planned and maintained tree plantations intermingled with vegetable cultivation plots which will absorb all the solid and liquid bio-waste generated in the residential area and produce sufficient vegetables needed for all the people of that residential area. Along with these there could be facilities for rearing small animals like rabbits, ducks, chicken, guinea pigs etc. for egg and meat purposes. Even goats can be reared using the household waste and leaves from the trimmings of the trees. Depending on the climate trees like drumstick, tree beans, A*gathikeerai* (*Sesbania grandifolia*) Jackfruit and mango trees or other fruit trees can be included among the tree plantation. Papayas and local types of bananas can be cultivated in such residential

areas. Fruit trees like lime, lemon, orange, grapes, guava etc. can be also cultivated. The houses of the residential areas should be constructed in such a way that there can be terrace gardens to cultivate vegetables and flowers. Delhi the capital of India is an excellent example of well greened city. Most of the areas in the city of Delhi are covered with trees combined with many parks and gardens.

There may be reasons for a country not to use any part of the land for agricultural purposes. For example Singapore has decided not to cultivate any crop except some vegetables a limited area but to import all other food items. Surprisingly even all the water they use is imported from another country. It has decided to invest in non agricultural enterprises in such an efficient way that it will have enough and surplus income to buy water and food from outside. And it has succeeded in this policy and everyone knows that it has one of the highest per capita income in the world. There are many reasons for Singapore to take such a decision: 1. Agriculture production is not at all economical; all over the world it is not a profit making enterprise; it is highly subsidized for the benefit of the consumers. 2. There will not be people ready to engage in farming and animal husbandry because they are considered low status occupations. 3. If the government runs agricultural production there will be large number of people employed to manage all the operations and for the payment of them itself will be a huge expenditure without any return. 4. Any operation in the agriculture or animal husbandry involves environmental degradation which will be another headache for the people and government. 5. Singapore is too small a country to get involved in too many types investments. 6. The net area available for cultivation according the above stated principle would be too small for any worthwhile involvement in agriculture or animal husbandry. Thus there

are many considerations before any country could decide to go for land use in agriculture. Climate could be another determining factor to decide whether a country should go for agricultural investment. A country which is covered under snow throughout the year or having all the land area above 33.3% percent slope cannot go for agricultural or animal husbandry operations. Then they have to go for other income generating or livelihood activities leaving the land for perennial forest cover.

The second law further implies that only 30% area of the land mass will be available for human involvement both for agriculture and non agriculture purposes. Everyone can easily understand the type of usages of land for agricultural purposes. The land use for non-agricultural purposes include villages, towns and cities, industrial areas, roads, highways, railways, airports, institutional and office complexes, sports and recreational complexes, residential areas and flats in the cities etc. Thus both for agriculture and non-agriculture purposes a maximum of only 30% of the landmass is available. Out of this how much land area can be allotted for actual agriculture and animal husbandry and how much should be allotted to non-agricultural purposes is still a question the people and governments should decide. Even the land use pattern for agriculture and non-agricultural purposes is also governed by the degree or percentage of slope and the area under forest cover. If more than 70% area of the land is hilly and above 33.3% slope then all that area should be placed under perennial forest. Thus it is not only the ecological percentage of 70:30 for forest to non-forest area, but also the degree of the slope of the land that decides the area under permanent forest; first and foremost all the land area above 33.3% should be placed under forest. If any area is left then only we should go for other land use patterns.

Third Law: Preserve all the flora and fauna both on the land and in the seas and water bodies on the surface of the earth. They are the bio-resources of inestimable value: environmentally, genetically, economically, pharmaceutically, socially etc.

This imperative also needs no explanation as we all know that without plant system no carbon-dioxide and oxygen exchange takes place and no animals, nor humans can survive without plant kingdom. All the plants and animals are tremendous storages of genetic wealth which have immense potentialities for numerous genetic evolutions, and the same can be used for breeding and genetic engineering. Science has developed so much, that gene pools of even dead and disappeared plants and animals can be stored for future use. Hence preservation all plants and animals is very important for the sustainability of all the valuable plant and animal resources on this globe. Again it should be reminded that perennial forests are the best habitat for all the microbes, plant and animal gene pools.

Fourth Law: A maximum of 30 per cent of the land only can be used both for food production activities like agriculture, animal husbandry etc. and for other activities like residential and institutional areas, commercial and recreational areas, transport and airport areas etc. The proportion of land allotted to both activities depends on the importance given to each sector by each country.

This law of eco-system is an important factor in the healthy maintenance of the eco-system of any country. Though the FAO/UN organizations stipulate only 31% of the area of a country only under forest cover, ecologically speaking at least 70% of a country's total area or all the land area at and above 33.3% slope should be maintained

under perennial forest cover to maintain the ecological balance. Therefore the maximum area left for all types of human activities including agriculture, animal husbandry, residential areas, industrial and institutional areas, transport and airport areas, sports and recreational areas etc., will only be 30% of the land area, although certain Institutional establishments along with its residential areas can be located in selected forest areas without hampering the nature and function of the forest landscape. This implies the adjustment of population of a country according to its available area for human use of which the sixth law speaks in detail.

However there are enough examples of countries which have made judicious use of their land resources like Switzerland and Singapore. Switzerland is a big enough country of 41,285 square kilometers but nestled in the snow covered Alps mountain range and Singapore is a small island of 728 square kilometers.

1. **Switzerland**: It lies in the heart of Europe, sharing its 1,935 kilometer long border with five countries: Italy, France, Germany, Austria and the Principality of Liechtenstein. The Alps cover almost 60% of the country with 49 peaks rising above 4000 meters; the Central Plateau is around 31% of the area and the Jura which is old administrative mountain settlement is about 11 per cent. The Alps mountain ranges cover most of the country, but only 11% of the population lives there. **The settlement areas cover only 7.5% of Switzerland's territory.** These include areas given over to housing, infrastructure (trade, industry and transport), water and energy supply, wastewater disposal, as well as green and recreational spaces. The proportion of actual agricultural land is low in Switzerland mostly consisting of permanent grassland and mountain pastures where tillage

is not practiced. However they have only the minimum required forest land of 31% as recommended by the UN, which is below the ecological requirement. Switzerland has a huge fresh water system: consisting of around 1,500 lakes which, together with other bodies of water like streams and lakes, account for 4% of the country's surface area. The country has 6% of Europe's freshwater reserves. The source of major European rivers like the Rhone, Rhine and Inn is in the Swiss Alps. The Ticino river is a tributary of the Po (Italy), while the Inn flows into the Danube (Germany). About 74% of **Swiss** GDP is generated by the service sector including the banking sector (World famous Swiss Bank, established in 1872) and 25% by industry. **The contribution from the agricultural sector is less than 1%.** The European Union (EU) is Switzerland's main trading partner. Around 78% of Swiss imports are from the EU, while 43% of Swiss exports are destined for EU countries. Being nestled in the snow covered Alps mountain range, it has a well developed mountain railways to promote tourism to provide millions of visitors a spectacular views of the famous Alps mountain range.

2. Singapore: It is one of the smallest counties in the world with 728 sq km with 0.9% area under agriculture but 23.1% area under forest. About 114 hectares of **land** are allocated for vegetable farming to provide fresh green and luscious vegetables to Singaporeans. Agriculture in the country is responsible for less than 0.5 percent of the country gross domestic product (GDP). But **Singapore economy is one of the most stable in the world, with no foreign debt, high government revenue and a consistently positive surplus.** The Singapore economy is mainly driven by exports in electronics manufacturing and machinery, financial services, tourism, a dependable airlines and the world's busiest cargo seaport.

Fifth Law: There can be agriculture land in the forest area or forest land in the agriculture area depending on the percentage of slope and size of the land.

The application of this law is a wonderful example and opportunity of judicious land use system in a country. Even in the forest there are leveled areas enough (a minimum of 50 hectares or 125 acres enough for 10 households) and suitable for agriculture with sufficient irrigation water availability. Such areas should be marked for sufficient number of agriculture settlers with adequate transport and market facilities. (NB: The students of ecology and environment may make a study of such forest settlements in different countries in the world and present papers on the same as a project work).

In the same way there can be forest areas surrounded by agricultural land. The Deccan Plateau in our country is a huge agricultural land dotted with many hills, mountains and rocky areas. They all should have been perennial islands of forest among agriculture tracts. Unfortunately most of it is barren hills and mountains with all the streams and rivers in them already dried up. Similar areas are there in the North Eastern States with valleys and forested mountains intermingling with each other. Unfortunately most of the forests on those mountains are getting cleared up year after year.

Sixth Law: Limit the population of each country at its carrying capacity. All the countries should maintain the population it can support within the carrying capacity of the cultivable land area or other income generating resources.

Carrying capacity per unit area of land was originally defined as the average number of cattle heads that can be maintained on a given piece of grazing land. The same

principle should be applied in the case of human beings in the case food and other consumable items. The available land area of any country cannot support endless number of people happened to be born or migrated into. In any country there is a limit to the production or procurement of consumer items. Basically it is a balance between the demand and supply. This problem is becoming crucial at a time when the population in certain countries is increasing by birth or by migration beyond its capacity to produce or buy through trade enough food to feed them. We also have to recognize that a given land area of a country has limitations in producing or procuring food items beyond certain level. There is a limit to the trade in bringing consumer items from outside. We must also remember that certain resources are non-renewable.

The problem is the same in the case of housing which is being solved to some extend by high-rise buildings which still have limitations. Remember 70% of the area has to be under forest cover for environment, water and climate sustainability; in short for the sustainability of the eco-system of the earth. Of the rest 30% of the land we have to divide between agricultural and nonagricultural usages, which roughly come to 50 per cent each of the original 30 per cent of the total land area.

Therefore following the law of carrying capacity of the land and its resources each country has to regulate the population it has to support. At the same time reallocation of population between countries which is already taking place now should be streamlined on the principle of "Carrying Capacity" of the land based resources. It involves control of population both by birth and by migration (immigration and emigration).

Seventh Law: Land use pattern is governed by the percentage or ratio of the slopes. All the slopes at and above 33.33% (1:3 = Vertical to Horizontal) slope should be placed under perennial forest cover. If the land area above 33.3% slope is more than 70% then all that land should be placed under perennial forest cover. If a country is having no land above 33.3% slope still it is advisable to maintain 70% of the area under forest unless they are too small in area like Singapore, Vatican, Monaco, Nauru, Tuvalu, San Marino, Malta, Granada, Barbados etc.

As a corollary to this law it should be the law of all the lands/countries that no land at or above 33.3% slope should be registered under any private ownership.

Greater the slope of the land more should be the perennial nature of the forest or vegetative cover it should have. Remember anything done in forestry, agriculture, and animal husbandry affect the environment directly. Some broad directives of land use pattern under this law are given under this law of nature.

The seventh law is to facilitate the preservation of as much soil as possible in the hills and slopes. As we saw already soil is the storage of water, harbour of forests and vegetation. As already mentioned soil stores up water during the rainy season and releases the same water slowly in the form of numerous springs, that emerges at the lower side of the hills and mountains which becomes feeders for streams and rivers. The unwritten law of nature is "If you violate this law you cause the springs and streams originating at the foot of the mountains to dry up and you shall suffer from shortage of water in the rivers".

Slopes at and above 33.3% are the minimum level beyond which no human or domestic animal activity should be permitted on the land area. No free grazing of

cattle or any other animals should be allowed in this range of slope. They should be covered with natural forest. It should be repeated again that no free grazing or controlled grazing of any other animals should be allowed in this range of slope. That is the only way to minimize the soil erosion on the slopes and hills. Unfortunately for many years this factor of the seventh law has not been followed and as a result millions of hectares of mountainous areas all over the world are denuded and made into deserts. Also people are not aware of this section of the commandment of the nature. Survey showed that no one among the land users knew that they are not allowed to use any slope at or above 33.3 per cent. Going against the fifth commandment is suicidal to the humanity and all the living organisms. Arguments such as "People need land irrespective of the slope, they need to live somehow" are apparently sound genuine demands. But in the long run they are detrimental to the whole humanity and to the whole nature. Following are the general recommendations for land use pattern based on the percentage/ratio/degree of slopes.

1. All the slopes above 33.3% should be placed under perennial natural forests with 100 canopy coverage except those areas that are covered with large rocks and grass lands. Even the rocky areas and grass lands above 33.3% slope should be forested as much as possible.

2. All the slopes ranging between 20 to 33.3% (1:3 to 1:5 vertical to horizontal) should be put under perennial crops like fruit trees, plantation crops or planted timber trees. But the springs originating in these areas should be preserved with a perennial protective cover of natural forest of 50 to 100 meter in radius around the spot the spring comes out.

3. All the lands having slopes ranging between 10 to 20 per cent (1:10 to 1:5 vertical to horizontal) slope

should be terraced before they are used for seasonal crops. This practice is very essential to control the soil erosion. Remember soil erosion leads to depletion of water and then to desertification.

4. Areas between 5 to 10 per cent slopes can be used for seasonal cultivation provided leveling and terracing or other soil and water conservation practices are adopted.

5. Only land between 0 to 5 percent slopes can be used for seasonal crops like cereals, millets, pulses, vegetables, flowers etc. without any soil conservation measures.

6. Area less than 0 degree slopes or low lying areas can be used for wetland paddy cultivation or any of the suitable forms of aquatic crops or fisheries and aquaculture. Any low land area should be maintained as water bodies and should never be filled in as is done in many places in India. In Bangalore, more than a dozen lakes are filled up, Chilka lake in Orissa is being reduced from all sides by the encroachers, low lying area of Kuttanad in Kerala and mangroves in many parts of West Bengal etc are being converted to lands for commercial and residential usages. Table 1 gives a summary of the recommended land use pattern as per the ratio or percentage or degree of slopes.

Here it should be noted perhaps very few planners and land owners or cultivators know this fifth law of nature and land utilization and it is high time that everyone should be aware of the fifth law of nature and its sub-divisions as indicated in Table 1.

Table 1: Recommended Land Use Pattern as per Slope of the Land.

1	2	3	4	5
No.	V/H ratio (ft/mt)[1]	%of slope (V/Hx100)[2]	Degree of slope	Types of recommended land uses
1	1/1	100.00%	45.0°	Under perennial natural forests,
2	1/2	50.00%	26.6°	Under perennial natural forests,
3	1/3	33.30%	17.5°	Under perennial natural forests,
4	1/4	25.00%	14.5°	Planted commercial forests
5	1/5	20.00%	11.3°	Planted commercial forests
6	1/6	16.25%	7.5°	Fruit trees, plantation crops,
7	1/7	14.30%	6.4°	Fruit trees, plantation crops,
8	1/8	12.50%	6.2°	Annual crops in small plot irrigation
9	1/9	11.10%	6.0°	Annual crops in small plot irrigation
10	1/10	10.00%	5.7°	Seasonal crops in plotted irrigation
11	1/12	8.30%	4.76°	Seasonal crops in plotted irrigation
12	1/20	5.00%	2.86°	Seasonal crops with irrigation
13	1/50	2.00%	1.15°	Seasonal crops with irrigation
14	1/57.29	1.7%.	1.00°	Seasonal semi-water logged crops
15	1:95.5	1.00%	0.60	Fully water logged crops
16	Less than 1% or negative gradient			Fisheries and aquaculture

Following picture (Fig 6) shows how the higher regions of a hill or mountain range is covered with forests while the lower levels are used for dairy farming whereas the lowest areas of the hills is maintained as a grass land. Of course the grass land could have been marked by contour bench terraces or contour bunding dotted with fruit trees. Here dairying is the land use pattern and we see the cows grazing on the grass lands. Instead of the grass land we can also have a cropping land. Thus the same land area could be used for various purposes. In the lowest area in the plain a runoff water collection tank could be constructed along with a well for drawing drinking water. Along with dairy farm one can have a piggery, poultry or goat farming. Along with the runoff water collection tank one can have a duck rearing unit. Thus the land use pattern can be different for the same area and by different owners.

Fig 6: Land use model on slopes and plain

Eighth Law: Roads, paths and other facilities in all the forest system or cropping system areas for better supervision and management, should be incorporated into the forest system in such a way that while collecting

forest products including timber trees, there should be no disturbance to the soil, water, plant and animal components in the forest system. Also it may be used as parks and recreational areas by people.

Forest products are of two types: minor forest products and major forest products. They are of very high value usage to humans and if they are not collected they will be lost to humanity. But they should be collected in such a way that the forest system should not be disturbed. Timber trees in the forest are not to be harvested according to the need of the people but according to the availability of trees of prescribed size and length. At present trees are harvested for timber and firewood by wood industries according to people's need both in quantity and quality. In that approach the harvesting contractors are not bothered about the environmental and other problems of deforestation. They resort to clear felling of the forest area they contracted and even from more area than allowed. Environmentally sound harvesting of trees will be done from the commercial plantation area at the range of slope between 20 to 33.3 per cent slopes where selected trees are grown for commercial purposes. Trees are harvested according to the availability of harvestable trees of certain girth and height.

Harvesting of trees for timber from anywhere in the perennial forest area should be done only by using cut-and-lift-off-technology (eg. by helicopter as is done in several developed countries) and not by cutting roads to drive in trucks to carry or to drag them by elephants or machines. As already mentioned only the trees of certain girth size and length should be cut and lifted without disturbing the trees and plants or soil around it. Which one should be cut shall be identified by remote sensing and other modern techniques.

Collection of minor forest products (broadly all the forest products except timber trees and sandal wood trees) also should be carried out with least disturbances to the forest eco-system. Quarrying if at all done should be done without disturbing the eco-system of the forest area and can be done in a planned way that it becomes a huge reservoir of rain or runoff water. The Blue Mountains in Australia is an example of a planned management of mountain forest eco-system with well laid out paths, parks, cottages and all types of recreational and trucking facilities. Japan is full of such well managed natural forest systems which are frequented regularly by the public who pay for their up-keep and maintenance. Even residential and institutional systems can be incorporated into many such mountain eco-systems provided they are well planned and maintained. Well planned and managed natural mountain forest systems can be a great source of revenue contributing a lot to the sustainability of the earth our eco-system.

Ninth Law: The area under agro-eco-system needs special care as it is the source all vital necessities for humans and domestic animals. Various agricultural activities are determined by the percentage of slope varying from zero to 33.3 per cent as given in table 1. The agricultural land also should have a well planned transport system linking to markets and cities.

Along with **forest system** equally important is the **agro-eco-system** which is primarily linked with agriculture and keeping of domestic animals for supporting the human life. Agro-eco-system means that part of eco-system or earth on which humans and animals are depending on for their day to day needs like food, fuel, fibre, fabricates, pharmaceuticals, feed and fodder etc. Hence maintenance of agro-eco-system in the proper productive condition is

very important and is an inherent duty of humans who are engaged in agro-eco-system. This is especially true in the case of rural people who depend on agriculture and related economic activities. Even the urban people also have to depend indirectly on the agro-eco-system for their various food items, clothing, housing and furniture materials, fuel wood, and medicinal plants. Hence the **immediate environment of human beings for their sustenance and development is the agro-eco-system.** Human life depends on the health of the agro-eco-system.

Following are the **key problems** with management of any agro-eco-system. They are: 1. Soil erosion, 2. Soil fertility loss, 3. Soil acidity, salinity and alkalinity, 4. Depletion of organic matter or humus in the soil, 5. Excessive use of chemical fertilizers, pesticides, herbicides, 6. Frequent change of hands in the management of agro-eco-system through the cycle of sale and purchase, 7. Lack of long term planning in the management of the agro-eco-system, 8. Excessive or deficiency of irrigation or no irrigation at all, 9. Disposal of crop wastes by burning and 10. Use of cattle dung as fuel: instead of recycling it through bio-gas plants to get both cooking gas as well as enriched organic manure etc. There may be more of such problems.

The **agro-eco-system** in its broad sense involves not only the so called agricultural land but also the forest land in the cultivated areas, all the water bodies where man is involved in fisheries and aqua-culture in passive or active form. Mere fishing in any waters is a passive engagement of man in the water bodies including the sea. But if he starts rearing, controlling, breeding, improving the aquatic flora and fauna then his involvement will be active and his active involvement in the water bodies can, not only affect the water bodies, but also the flora and fauna he deals with for

his livelihood. Similarly he can be **involved in passive and active ways in the water bodies like streams, rivers, ponds, rocky and uncultivable areas within the agricultural land.** If he is collecting the minor forest products only his involvement will be passive but if he practice shifting cultivation or cutting the forest area for small and big timber or sets forests into fire or converts forest area into farming or cattle ranging then his involvement will be active. **His active involvement may be constructive of destructive: positive or negative.**

Humans in the Eco-system

As we move from microbes to humans the **dependency syndrome** of each of the living components on all other previous components increases. Finally humans, though they are the last to appear on the earth depend not only on all the five nonliving components but also on the microbes, plants and animals for their existence and development. At the same time their ability to **control and manipulate** the same components will also be maximum, compared to all other living beings. **Thus though man is the master and manager of all the components in the Nature yet he is the most vulnerable component in the same Nature.** If anything happens to any of the other nine components his life will be affected drastically: or even human life will be impossible. Similarly if anything happens to the plant kingdom then all the animals and humans will be affected. In the same way if the soil or water in our eco-system is eliminated then the plant life will be affected and consequently both animal and human life will be affected. **In other words the equilibrium of our eco-system is governed by the inter-dependence and inter-relationships between each and every component in the eco-system.**

Administratively a village, district, a state or country can be also our immediate eco-system and environment at the same time. Their natural ecological set up is more permanent than all man-made physical or economic structures. Again depending on the nature of the ecological structure the economy of the people varies. Hence we find the economic base of heavy rain fall areas like West Bengal, Assam and Kerala are different from the economies of dry and desert areas like Rajasthan or hilly areas like Uttarakhand, Himachal Pradesh, and Jammu Kashmir etc. are different from low rain fall areas of Deccan region or dry regions of Rajasthan and Punjab.

To manage all the agricultural resources, there should be well planned and interconnected road and transport system in all the regions of agro-eco-system.

Tenth Law: All the water bodies like springs, streams, rivers, lakes, ponds etc. whether natural and man-made, whether in the forest system and in the agro-eco-system, should be maintained and improved with a protective cover of vegetation around or by the sides of them.

Any water body requires a protective layer of mixed natural vegetation; that is a natural law or nature's imperative. There are many scientific reasons why a stream in the forest dries up as soon as the vegetation around or on both sides of it is removed. Just like any animal requires a protective cover of hide and hair or clothes for human beings so too a water body requires a sufficiently thick layer of natural or planted mixed vegetation around it or by the side of them for its survival, well being and proper functioning. As rule all the ponds and lakes should have a thick layer of well packed clay at the bottom to reduce percolation of water to the minimum. Generally this happens naturally. Similarly all the streams and rivers should have as many check dams,

anicuts or barrages constructed intermittently at as many suitable locations as possible in their course of flow so that as much water as possible can be impounded allowing percolation of water to both sides of them.

It is a general rule that all the catchment areas of all streams, rivers and dams etc. should be under perennial forest cover. Similarly the origin of springs usually originating at the foot of the hills and mountains should have a permanent vegetative cover with a minimum radius of 33-100 meters, so that the spring remains in the eye of the circular vegetation. The eco-system of such springs should be preserved in its original nature. If all the springs in a mountain range is thus protected then all the streams which are fed by those springs will never dry up and the river that is fed by the springs will never dry up in the summer and will not flood unduly during the rainy season. At the same time the silting will be reduced to minimum though silting cannot be completely stopped. At present all the rivers in India are drying up in the summer and flash floods occur during the monsoon. Preservation of springs, streams and rivers in their original eco-system is very important for the preservation of the eco-system of a watershed area as big as a district, state or a nation. No human interference in terms of agriculture, residential complexes, institutional or industrial complexes should be built near such springs so as to disturb the eco-system of those springs.

Eleventh Law: Follow the watershed method to maintain the agro-eco-system of the land area. Watershed is a comprehensive method to restore, develop and to preserve any agricultural land to maintain it in a healthy and productive condition between soil, water, air, light, microbe, plant, animal and humans in the nature.

Watershed is a geographical area of any size defined

by boundary line with reference to a specific point on the drainage which drains all the water from it. The drainage may be a stream or a river draining water from a specific watershed. Any spot on a stream or river can become the point of reference to a watershed. An imaginary line can be traced from this point to the left or to the right encircling the watershed and comes back to the same point. This line is called demarcating line or divider or dividing line or ridge line because that line moves over a ridge that serves as a boundary to the watershed under consideration. From this ridge rain water flow into the watershed or away into another watershed depending on whether the rain drops fall on the inner or outer side of ridge line. The Lower the position of the reference point on the river or stream, greater will be the size of the watershed. The size and shape of the watershed also depends on the location of the reference point taken on the stream or river. Obviously a river will have many tributary rivers and each one of them will be draining a separate small watershed. The water may be over ground or underground; it may be rain water or ice melted water. **In short watershed is an area which drains water through common point of drainage.**

Soil and water has such an intimate relationship that without soil, water cannot be held or stored and without water soil cannot be productive. All the living organisms depend on soil and water. Soil is generally stationary while water moves around in the soil or over the soil. **Water can move inside the soil in all directions while on the surface it moves towards the lower areas: water moves from the higher potential to the lower potential.** The water in a pond or lake may look to be stationary at a particular time of the year. But even in a pond or lake water moves downward, sideways and upward while we feel that most of the water remaining stationary in the pond or lake. In the

rivers and streams the water is always on the move. This movement of water is part of the water cycle in the nature. Every watershed receives certain amount of water through rain or some other source during the year. **As a thumb rule we can say that one-third of the rain fall will be absorbed into the soil in the form of seepage, one-third will evaporate back into the atmosphere and one-third will form surface flow or run off which when collected from all direction into several streams first and then several streams will join together at different points to become a single river draining water from the watershed under consideration.**

The watershed management consists in reducing the speed and quantity of the flow of water on the soil surface so that a maximum of the rain water can be seeped into and stored in the soil or into the water holding structures like perennial forests, check-dams, reservoirs, ponds and other water holding structures so that water is made available to all living beings in the watershed throughout the year. Reduction in the flow of water reduces automatically soil erosion and encourages conservation of soil and organic matter. **The aim of the watershed management is to conserve soil and water in a watershed area and to build up organic matter in the soil.** As already mentioned a big watershed consists of many small watersheds termed as midi, mini, micro and macro watersheds: all joining together to form huge river basins like Ganges, Brahmaputra, Mahanadi, Godavari, Krishna, Kaveri etc. Even a small garden plot can be considered as a watershed. Therefore soil and water conservation is implemented in each of them individually as well as collectively. **Depending on the percentage of the slope a watershed can have all types land and water utilization mentioned under the fifth law of nature.**

Twelfth Law: All agricultural land should be structured permanently for better management. They should be plotted in such a way that maximum soil and water conservation is ensured. Irrigated lands should have proper irrigation and drainage channels fitted in, while structuring the farm and any excess runoff water from the plots should be collected into non permeable ponds or tanks for future use in the farm.

A school or college if it has to function properly it should have a well structured building for doing all types of functions and activities. A hospital cannot be run on a permanent basis in school building though some temporary health service may be done. A corporate office cannot function in a temple or can we run a computer software programme without having a hardware set up. Everything needs a proper physical structural setup. So too, to run a farm efficiently and effectively it needs a well planned structural set up and functional set up established within the set up of a watershed management. It should have proper roads and paths, farm house, store of farm machines, implements, chemicals and fertilizers, irrigation and drainage system, farm waste management system, temporary storage for farm produce etc.

At present almost all the farm lands in India are unstructured small plots cultivated by half naked, starving and emaciated, illiterate poor farm workers struggling like ants and bees. The Indian farmers never thought of structuring their farm lands permanently. Every year and every season they plough in their traditional way and prepare the soil, make the bunds and irrigation channels and saw the seeds, do the weeding and other intercultural operations, make the threshing floor, harvest and thresh manually every year in their traditional ways. the plots are

irregular in shape as they are made in a half hazard way; they are uneven in its level, the boundaries of the plots are not well demarcated; the irrigation channels are not lined to minimize the seepage lose of water; the paths and roads in the farm are not laid properly and hence transport becomes difficult or impossible; there may be trees and rocks within the cultivated area; the farmer has no clear idea of the area of the plots or his farm land; the land records are manipulated; everything is done without any planning or calculation. In most of the developing or under developed countries the farmer just ploughs and throws the seed. He takes the soil for granted and even ignorant about the methods of maintaining the soil structure and texture in the optimum productive way. He spends more time and energy in all the farm operations using large number of labourers of humans and animals. He also never keeps an account of the income and expenditures; nor does he keep a record of the farm assets and liabilities. In many parts of the country still shifting/Jhum/slash and burn cultivation is going on.

Whereas in a structured farm all the plots will be of regular shape and definite area, made within the space between well laid out paths and irrigation channels; approaches to each and every plot for humans, animals or farm machines are clearly laid out; similarly irrigation inlets and drainage outlets into and from each plot is well structured so that each plot can be irrigated or drained separately without interfering into the other plots; the management of soil structure, texture and tilth is given special attention and all the operations in the soil becomes easier; the plots are laid out for irrigated, un-irrigated, seasonal, annual and perennial crops, the soil in each plot will be maintained in the optimum productive condition; application of manures and fertilizers can be done

more efficiently and the maintenance of the soil fertility becomes easier; the movements of people, animals and farm machineries becomes easier, all the farm operations and movements in the farm becomes easier and takes less time; the records of expenditures and income of the farm, even plot by plot and crop by crop, season by season, input by input can be maintained and comparison can be made between years and improvements can be done. The uncultivated area in the farm land is planned for forestry and tree plantation for firewood and timber or for animal rearing and grazing; the farm buildings required for various purposes also will be constructed in the uncultivable areas of the farm. The principles of watershed management will be applied in the structuring of farm. In other words the whole farm will be an eco-system and set environmentally in the best way possible so that the farm will be one or a combination of several watershed eco-systems. All farms should be connected with motorable roads linking with nearby towns, markets, district headquarters etc.

The farm area of G.B. Pant University when it was in the former Uttar Pradesh was an example of a very well planned and set up farm for proper management as several ecological systems as it had a cultivated area of fifteen thousand acres. It was planned and set up the experts from Illinois University in 1960's. The thousand acre research farm is one of the best in the country in its structuring and lay out with a huge laboratory with all facilities for all types of agronomic research projects and programmes. It takes years to convert the soil into an optimum fertility status; but to maintain the same status we need a permanent structure and a monitoring system. In a well established and maintained eco-system there will be established a permanent organic matter and water cycle system. All the used water in any hostel or in any staff quarter was drained

into the farm ponds for recycling. It had inbuilt structures to withstand the fluctuation effects of the heaviest rainfall and flood or the severest drought conditions. The irrigation and drainages will be structured in such a way that the excess water drained from the plots will be stored at suitable locations so that it can be reused for irrigation.

In a well structured farm there will be facilities for composting and recycling all the organic materials generated in the farm. Thus regular water cycle and organic matter cycle will be maintained which is the most important characteristics of a watershed-eco-system. A well structured farm will have sufficient area to use efficient and newly evolved agricultural machineries and other technologies. It should have a minimum area of 10 hectares (25 acres) of area.

Small farm holdings are a curse to the agro-eco-system. It will not preserve the organic matter in the soil at the minimum optimum level leading to depletion of soil fertility and yield. It will not support the farming families even for their sustenance and much less for their developmental needs. They will be ever in a confused state of mind whether to cultivate or sell it. They can neither live on it nor can they leave it. Sustainability of the farming family is a key factor in the maintenance of national and global eco-system. Unstructured farm holdings become a liability to the eco-system and eventually leading to wasteland formation and eventually desertification and migrating out of the people.

Structuring of the farm lands into viable units is necessary for planning and implementing long term farm land use plans and cropping patterns that are economically viable, environmentally suitable and ecologically sustainable. Along with structuring of farm lands mechanization of most of the farm operations is also a need in the long run. Any

runoff water from it should be collected into non-permeable ponds or into any such water collection structures under or over the ground for future use.

The area of all the farm lands in any country should be of minimum operational size and in India they should be structured in accordance with the land reform proposed in 1973 or some other better size structuring of farm lands. The Central Land Reform Committee 1972 suggested the division of the land into the following sizes of viable land holdings.

10 to 15 acres for irrigated land with two assured crops (4-6 ha) better to be 15 acres

27 acres for partially irrigated land with one assured crop (10.8 ha) better to be 30 acres

54 acres for un-irrigated or rain fed land (21.6 ha) better to be 60 acres

The rationale behind this division is that from the income of the land holding the operating family should be able to meet all the basic requirements for its existence and development. Requirements for human existence are food, fuel, clothes, housing, medicine, rest, etc. while the things required for personal and human development are education, recreational and reading facilities, infra-structural facilities, institutional support, decently furnished housing etc. In terms of the cash the amount can be determined for an individual or a family of average number and also according to the price fluctuation in the market both sold and bought.

With reference to India except in Punjab, Haryana, West Bengal and Kerala implementation land reform was carried out in a lackadaisical way in all other states giving rise to absentee landlordism along with continuation of absentee

bonded labouredness. In 1976 an act (Gvt. of India 1976) was passed abolishing the bonded labour and thousands and lakhs of bonded labourers were released: most of them for name sake. Absentee landlordism and absentee bonded labour continued in many parts of the country especially in Bihar, Uttar Pradesh, Orissa, Madhya Pradesh etc. Along with structuring of the agricultural land the population depending directly on agriculture should be reduced to minimum as have been done in most of the developed countries where the population directly depending on agriculture is less than 5 per cent. Manual labour on the farm land to a limited extend is good but beyond that it is very dehumanizing. That is what is happening in India 263 million farm workers on the farm lands. We have very high percentage of population depending on farming on small pieces of land while equal or more number are depending on the land as landless casual labourers for very low wages adding a lot to the socio-economic problems of our country making unsustainable ecologically, economically and socio-politically. **Structuring of agricultural land is essential for sustainability of the agro-eco-system as well as abolition of absentee landlordism, bonded labouredness and high percentage of illiterate and low productive farm labourers.**

Thirteenth Law: The structured farm lands should never be subjected to law of inheritance to divide and subdivide endlessly generation after generation.

A structured farm operates like an organic body or a compact machine. Separate one or two organs from a human or animal body it will not be able to function; or dismantle a machine into two or three sections; the machine will not work. Similarly a well structured farm should not be divided and subdivided under any circumstance. At present the law

of inheritance practiced in many parts of the world divides and subdivides the farm land into smaller landholdings. One family owns several pieces of land at different locations. Ultimately the family that owns them cannot cultivate or will not cultivate as they do not yield any income; it will be a loss to cultivate such small pieces of land.

A well set farm land should be managed by the same person on a long term basis. Division and subdivision farm land under the law of inheritance frequently changes the ownership of the small pieces of land. Frequent change of hands in the farm land management will not be helpful to manage it economically or ecologically. Proper soil and water management in a farm requires long term plan and meticulous execution. Further a well or water source or an irrigation system set up in a farm cannot be divided nor can we have any division of the drainage system.

The present law of inheritance is contrary to the principles of ecological farm management. In many countries the family holding is not divided but one of the children inherits it and takes care of it continuing the system already established while other children will look for jobs in non-agricultural sectors. Therefore all the farm land will have continuity in the management of all the operations. Similar should be the practice in all the other farm related enterprises like fisheries and aquaculture, dairy farming, beef cattle farming, pig farming, poultry farming, forestry etc. Any farm land should be part of a watershed system; and even a single farm may be part of one or more watershed system. In any farm related operation the organic matter cycle and water cycle should be established and maintained in order to keep the eco-system in a vibrant and productive condition.

Land for landless is a catchy slogan and goes well with

ordinary people. But people mix up land for agriculture and for other purposes like housing, industry, institutions and service sectors. Hence we must make a distinction between land use for agriculture and nonagricultural purposes. As in most of the developed countries less than 5% of the population only should be directly depending on farming but a large population can be employed in agri-business other than direct involvement on the land. Landlessness in India as given in table 2 is on the increase as is the case with most of the developing or under developed countries. It is high time to realize that landlessness is not the real problem but lack of skill and capacity building in off-farm sectors.

Table 2 The state of Landlessness in sixteen Indian States

No	States	House holds in percentage	No	States	House holds in percen-tage
01	Andhra	73	09	Orissa	54
02	Tamil Nadu	73	10	Maharashtra	53
03	Kerala	72	11	Chhattisgarh	47
04	West Bengal	70	12	Karnataka	47
05	Punjab	65	13	Uttar Pradesh	45
06	Bihar	65	14	Rajasthan	38
07	Madhya Pradesh	55	15	Jammu Kashmir	22
08	Gujarat	55	16	Himachal	22
				All India	56

All the developed countries and even China are moving systematically to a structured farming system. Farming is no more a way of life on the farm site as it was in our

country but it is a full-fledged business that could employ sizable population of any country in off-farm activities. **The greatest curse to Indian agriculture is the age old caste and tradition bound involvement in all agricultural, animal husbandry and aqua-cultural operations. Indian agriculture needs to be liberated from this caste and tradition bondage before it can be liberated from the economic and technological disabilities.**

Fourteenth Law: Organic matter and water cycles should be established in every farm holding. All the bio-mass or organic material generated within every piece of agricultural land area should be converted into organic manure and should be incorporated back into the cultivated soil to establish and maintain "Organic matter cycle". The age old practice of burning of any bio-material is diametrically opposed to the natural law of "Organic Matter Cycle". Burning of any organic material is the most harmful human activity contrary to the sustainability of nature.

"Organic matter is the soul of the soil"; just as a body without soul is dead, so too soil without organic matter will remain lifeless and unproductive. Hence all the organic matter generated within any agricultural land should be converted into organic manure and should be incorporated into the soil to maintain it's productivity. Hence nothing of any organic matter should be burned except firewood for fuel purposes, the disease infected materials of plants, animals and human beings. In many countries cattle dung mixed with straw is used as fuel. Such burning of any organic material is totally against ecological principles and practices.

As already mentioned **Organic matter is the soul of the soil**. This is all the more true in the case of the cultivated soil. A soil without organic matter turns out to be barren.

And the only way to maintain the organic matter content of the soil is to incorporate all the organic matter that is generated in that land. They should be composted to convert into organic manure which can he incorporated into the cultivated land. Such organic waste recycling should be practiced by everyone whether living in rural and urban areas. Produce as much organic matter as possible and supply to those who use it or supply to a common pool of organic manure. Depending on the raw material different grades of organic manure can be prepared, packed and marketed. Somebody can make a business out of it.

There are several methods of converting the biomass into organic manure. Pit and silo methods are the ones usually employed in the rural and semi urban areas. Pit methods are suitable in arid regions but unsuitable in medium and high rainfall areas; whereas, silo method of composting is more suitable both in arid and rainfall areas. Composting refers generally to natural method of recycling the organic material. There are also several other industrial and mechanical methods of recycling the organic materials and other wastes. Wastes from coconut farms, tea gardens, rubber and coco plantations sugarcane and banana plantations need special technology to convert the wastes into organic manures. Adopt any method which is most suitable to the place and people. The point is that all the organic matter generated anywhere in a country/state/district/block/village/farm/household should be converted into organic manure. The importance and need for organic agriculture is known to everyone. For various methods of composting refer to articles on "Composting", Booklet No. 64, and "Silo Method of Omni-Composting", Booklet No. 617. When large amount of organic wastes are involved in composting, "Parallel Long Silo Method", Booklet No. 675, may be more suitable. These methods are utilizing

the natural process of composting that takes place in the nature itself. The only drawback is that it takes more than a year and a half to compost a mixture of all types of rural agricultural and household wastes.

One thing which is already practiced fully or partially at different percentages in the rural agricultural sector is recycling of agricultural and household waste through several domestic animals like cattle, goat & sheep, pigs, chicken etc. such practices are highly recommended. In these cases the dung of the animals and the animal shed wastes are collected and deposited into the composting structures. The dung of various types of animals, kitchen wastes and even human faeces are recycled through well constructed biogas plants to produce the most valuable fuel gas both for domestic and industrial purposes and the much needed organic manure. The residual slurry that comes out of the bio-gas plant is excellent semi-liquid manures which can be used into the field along with irrigation water or as liquid manure to each plant or trees after diluting it at least 4-5 times. For dilution any type of non-potable water including sewage can be used provided it has no harmful chemical and industrial wastes.

Besides these natural methods as already mentioned there are several mechanical and industrial methods for treating the urban organic and inorganic wastes. Such methods are highly technical and costly but needed for urban areas with the support of the respective governments. The only suggestion is try to use the most cost effective methods with maximum return.

Above all the soil and the organic matter generated in the farm land is not managed properly nor incorporated or utilized. Most of the time all the organic materials generated in the farm is burned. Rampant burning of the cow dung in

India is an example colossal organic matter loss in the agro-system: so too the burning of paddy and other crop stubbles in India causing immense air pollution. Paddy straw is an excellent raw material for hard board manufacturing which is very much used in packaging industry.

Fifteenth Law: All the bio-mass or organic material generated within every piece of agricultural land area should be converted into organic manure and should be incorporated back into the cultivated soil to establish and maintain "Organic matter cycle". The age old practice of burning of any bio-material is diametrically opposed to the natural law of "Organic Matter Cycle". Burning of any organic material is the most harmful human activity contrary to the sustainability of nature.

All the biomass generated in any agriculture land should be composted and be recycled back into the land. Regular recycling should be a common feature in any farm land. In all the farm lands there should be suitable and permanently built composting structures. **The age old practice of burning everything is totally against environmental health.** The ash resulting from the burning contains only potassium and calcium while the organic manure resulting from the composting contain all the 17 essential elements required for the plant growth plus the life giving and sustaining organic matter called humus. Organic matter build up on farm lands should be shared by everyone even those who are involved directly into the farm operations. Recycling of all organic matter is an essential function for maintaining the sustainability of the eco-system.

Sixteenth Law: The price of agricultural products should be decided by the producer based on the cost of production and cost of family living. Adequate remuneration to the people involved in the primary sector

is a precondition to the well being of the agriculture sector.

The people who work in the primary sector are those involved in occupations like cultivation of crops like cereals, millets, pulses and vegetables, rearing of various types of animals, fisheries and aquaculture including those working in salt pans, orchards and plantation crops, forestry etc. In other words they are the people who work with nature and natural resources directly; they work on the soil, in rain, in the sun, in cold, during the day and in the night. They are engaged in their work more than eight hours or at times even for twenty four hours of the day. Energy wise a man who works with nature on the land or on the water/ sea spends 3500 to 4000 kilo-calories per day. Often their family members are also involved in the work without receiving any remuneration for their work. The people who own the land and other natural resources are not included in the primary sector; they are only owners and managers belonging to the tertiary sector.

At present none of the people who involved in the primary sector are paid adequately to lead a decent human living. The question of education of their children and other human development needs do not arise in their life. How is it that the present human social system allows a farmer to work on the land without even getting sufficient income not only to maintain his family but also incurring loss year after year. In the present system he is not only a slave not only of the nature but also of the society he feeds, clothes, houses by providing timber and other fabrication materials. He borrows heavily for his day to day living. As class of people **the farmer is born in debt, live in debt.** Under that condition he will not be able to maintain the farm land ecologically sustainable way. He will be like a taxi driver who does not get enough to maintain his taxi;

soon his taxi will stop running. The poor farmers engage themselves in their farm lands without maintaining its eco-system. Slowly the farm land will turn into a waste land and a desert. There are many examples of farmlands becoming deserts due to improper utilization of the land resources.

Seventeenth Law: All capital investments in the farm sector should be borne by the government and farmer should be dealing only with the running cost of agriculture. Economic and social sustainability of the farmers should be ensured.

All capital investments are long term expenses or at least not recurring ones. Clearing of the farm land and structuring of a farm like terracing with farm roads between terraces is perhaps the first capital investment. This is done once in the life time of the farmer and farm land. Another capital investment may be installing an irrigation system with pump sets in the structured farm. A third may be a farm house for keeping machineries, tools, agri-chemicals, fertilizers etc. A fourth may the machineries, implements, tools etc. Farm machineries may be bigger and costly ones like tractors, harvesters, combines etc. Most of these are one time or long term huge investments which the farmer will not be able to do. Hence such things should be done by the governments on a grant basis. All these types of expenses granted by the government is in general called subsidies. All the European and North American farms are given such subsidies with the result the farmer is only the operator and day to day manager of the farm. Almost all the inputs are provided at the farm door step and all the products from the farms are lifted by the government or government appointed agencies. Whereas in India the farmer has to bear all the capital and running expenditures besides he is the labourer and driver of his tractor and

operator of farm machines etc. He is the transporter and marketer and accountant. In all other fields different works are carried out by different people whereas in Indian agriculture all the investments and operations are done by the farmer besides he is the investor and banker to provide finance. In this connection a verbal communication to me by a Dutch developmentalist is worth recording.

He told me that when a large tract of land was reclaimed from the sea and made it into a cultivable area, which of course took many years. The reclaimed land is divided into plots of 25 acres each with permanently established drainage facilities and other needed farm structures. When a certain number of farm units are ready for distribution among the prospective farming families, usually couples interested in farming, the government appointed officers will invite applications from prospective farming couples. They are short listed and call the aspirant couples for interview. At the interview they are scrutinized for their suitability to run a farm and the selected candidates are allotted one plot each of 25 acres to grow a particular type of fruit or flower crop. All the inputs like saplings, manures and fertilizers, pesticides etc. and even the guidance on how to use them all are provided. Their only job is to produce a good crop. During the growing season they are given all types of assistances from planting to harvesting and marketing. Over a phone call all problems are solved. A farmer there is only to produce; all other operations in the farm is done by other agencies. The common rule of one man one job is applied in agriculture also. If a farmer got fed of the job he leaves the work and farm, it will go to some other deserving family. The farmer never owns the land he cultivates. Land is owned by the government and farmer is only an employee. It is high time that India thinks of such ways of management in the farm sector. The hereditary inheritance

of landed property is curse on the Indian agriculture.

Eighteenth Law: All the urban and industrial non organic wastes whether, chemical, medical, in liquid or solid form should be treated to remove all the harmful substances from them before recycling them into their byproducts. All the organic wastes should be converted into manures to be used in the farm.

Processing of urban wastes both solid and liquid is very important for maintaining a healthy environment in the urban areas. The urban organic waste converted into organic manure can be used for terrace gardening or pot-culture to cultivate flowers and ornamental plants, vegetables and even certain type of fruits. The shallow soil cultivation means cultivation that requires one foot or less than one foot soil. Almost all the vegetables can be grown within the soil depth of nine to twelve inches. Some of the crops like onion, garlic, lettuce, radish, potato, beet root, turnip, carrot, tomato, beans etc. can be grown in 6 inches soil placed in mud pots, in shallow beds, boxes, sacks or in any other suitable containers. Terrace gardening is becoming popular in many urban areas. A family of five to six requires 250-300 gram each root, leaf and pod/seed/ immature fruit vegetables per day. These can be grown by the family from an area of 30x20 ft (600 sq.ft.). Just as a family of five or six, require a minimum housing area of 30x20 ft. inner area, a terraced area of 30x20 ft is enough to grow enough vegetables for the same family. Similarly a vine or two of grapes, a few tomato plants and different kinds of burry plants can give the family the necessary fruits per day.

Now-a-days the urban housing colonies are done with such ideas in mind. Terrace and balcony gardening for producing luscious vegetables and flowers is slowly

becoming popular. Six to nine inch soil depth is more than enough to produce most of the vegetables. And such organically produced vegetables will prevent the health hazards due to use of vegetables produced with pesticides and chemicals. Fifteen to twenty minutes work per day is more than enough to produce all the three types of vegetables and herbs for any normal house hold use.

Nineteenth Law: Reduce the human induced environmental atmospheric pollutions or pollutants, weather solid, liquid or gaseous, to the minimum..

Linked with eco-system and ecology is the term **"environment"** which simply means the **surroundings** of any living being single or community. Environment is always defined with **reference to a living being.** Hence we have the environment of a man, animal, plants or even the microbes. Environment can be terrestrial, aquatic and atmospheric. The environment of any living being determines the life of any living being: its birth, growth, development, its ability to do any work, to flower and fructify and finally to die and decay to mingle with the nature. **Yet man is able to influence his environment very much even to the extent of changing it completely towards positive or negative directions.** He can even destroy his environment just by neglect and carelessness. Setting fire to forest while having camp fire, clogging the drainages by throwing away carelessly plastic wastes into them, polluting the rivers by dumping all types bio-wastes from tanneries, paper and sugar factories or diverting urban sewage are some of the ways of polluting the environment. Any improper waste disposal including human faeces and medical wastes pollute the environment so dangerously.

Gaseous forms of pollutants like Chlorofluorocarbons (CFCs), hydro-chlorofluorocarbons (HCFCs) and halons

destroy the earth's protective ozone layer, which shields the earth from harmful ultraviolet (UV-B) rays generated from the sun. CFCs and HCFCs also warm the lower atmosphere of the earth, changing global climate. Figure 1 shows the summary of the study by Minnesota Pollution Control Agency (MPCA) working with industry, residents and government to reduce the damage done to the ozone layer and global climate by CFCs, HCFCs, HFCs and related chemicals. Use of pesticides, carbon-dioxide and Chlorofluorocarbons (CFC) emitting activities are polluting the environment. Though CFCs are nontoxic, nonflammable chemicals containing atoms of carbon, chlorine, and fluorine they can pollute the air system and reduce the oxygen availability to all living beings which depends on oxygen. CFCs are used in the manufacture of aerosol sprays, blowing agents for foams and packing materials, as solvents, and as refrigerants. Atmospheric pollution is one of the biggest concerns of the present generation. The following diagram (Fig 6) clearly shows the sectors which are responsible for the emission of green house gas emission.

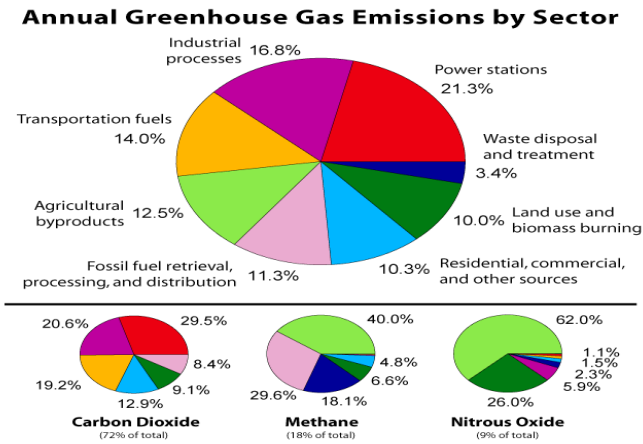


Fig 7 Annual Greenhouse Gas Emission by sector

As the data shows fossil fuel based power stations are responsible for 21.3% of the annual green house gas emission while Industrial process is responsible for 16.8%, transportation fuels 14%, Agricultural by products 12.5%, fossil fuel retrieval, processing and distribution 11.3%, residential, commercial and other sources 10.3%, land use and bio-mass burning 10% and waste disposal treatment 3.4%. Among the greenhouse gases carbon dioxide holds 72% share while methane and nitrous oxide have the shares 18 and 9 per cent respectively leaving 1% to other insignificant gases. Nearly 70% of the share of carbon dioxide emission is accounted by power stations, industrial process and transportation fuels; while 70% of the methane production is by agricultural byproducts and fossil fuel retrieval, processing and distribution; whereas 88% of the share of nitrous oxide emission is by agricultural byproducts and bio-mass burning.

Though waste disposal and treatment emits on 3.4% of the greenhouse gas improper waste disposal in the untreated form is perhaps the most serious environmental problem on the surface of the earth forming the best substratum for the growth and spread of all kinds of human and animal diseases. Wastes are mainly two types: bio-degradable and non-degradable. The ideal is to convert all the bio-degradable into organic manures and incorporate them into the farm lands to improve the physical and chemical condition of the soil while recycle or reuse all the non-degradable wastes. The wastes from chemical industries and hospital need special treatment to neutralize their adverse effect on the environment.

Twentieth Law: Use more and more of renewable types of energy sources like bio-gas, solar, wind and tidal waves instead of the fossil sources. Solar radiation should

be used for generating electrical power connected to the national grid. Similarly solar energy should be used for cooking food and for heating water and other purposes.

At present we are depending more on fossil source of energy which is nonrenewable. According to scientists, time is fast approaching when the fossil fuel sources will be exhausted. At present everyone is plugged into the national grid for the electricity for all his domestic electricity need. The national grid depends largely on coal and hydro-electric projects for power generation. Similarly as far as possible people would like to use cooking gas which are available in cylinders. All these sources of energy are becoming scarcer and scarcer and day will come when they will not be available. Therefore it is high time that we start using renewable sources **like biogas, solar power, wind and tidal waves.** All the private houses, office complexes, institutions, shopping complexes, parking complexes, should be fitted with solar panels to generate electricity and stored up solar energy for heating water and rooms. Fixture of such power generating gadgets on to the building should be a regular and compulsory feature in the future. All the water canals should be fitted with solar panels both for power generation as well as to reduce the evaporation of water from the canal. In the same way a large portion of all the highways and roads could be covered with solar panels to produce electricity which should be linked to the national power grid. Such programmes will reduce the stress on travel due to oppressive heat from the sun. Such arrangements will also reduce the repair and maintenance cost of the roads and highways.

Similarly all the domestic wastes and human faeces should be used to produce bio-gas to be used as cocking or other forms of energy needs. China is a model for producing

household level bio-gas and organic manure in the form slurry. The surplus production of electricity and gas should be sold to the national grid of electricity and gas. Thus there will be incentive for the people to produce electricity and gas in their full capacity. Similarly power generation should be carried out wherever possible from wind and sea. Similarly small scale hydro-electric generation should be allowed at the state, district and block level by private and public sector enterprises.

Twenty first Law: Facilities for collection, storage and use of rain water should be part of the construction of every house and institutional complex. Remember water stored in the absence of light or air or both will remain potable for any length of time.

We have already seen that reforestation of all the areas above 33.3 percent or 15 degree slope would increase the storage of rain water into the forest ecosystem and activate more springs and in the long run increase the rainfall. Whatever be the rainfall rate of the place the practice of rainwater storage should be practiced by every household and institutional complexes. Nothing new about such practices; people of Rajasthan have been practicing the same for hundreds of years and were collecting runoff water on the land into cement plastered wells. Now they have started collecting roof water by those who have pucca roofs for their houses. In many parts of the world and in India roof water collection is becoming a practice by law or by free will. What is required is to make rain water collection compulsory for every household with pucca roofing. Similarly roof rain water collection should be made compulsory for all the institutional complexes like schools, colleges, hospitals, sports complexes, auditoriums, shopping malls, churches, temples, mosques etc. Such

practice will reduce the load on ground water extraction.

Twenty Second Law: One's own body is the most intimate environment to any person. Management of one's physical and mental health is essential for ensuring a healthy population in a country which is an essential component for a healthy environment and earth eco-system. Healthy nutrition and healthy environment are the two necessary conditions for a healthy population. Unhealthy and irrationally behaving population is a dead weight on the eco-system of any country.

It is an established fact that most of the sicknesses and low body resistance to various diseases is due to under or mal-nourishment. The problem starts at the time of conception and continues till to the death of an individual. The rampantly practiced mother and child programme shows nothing but the nutritional deficiencies in the systems of food intake practices. Most of the pregnant women and lactating mothers do not know what type of food should be taken during gestation and lactation period. Further many among them even if they know or are told or taught the proper nutritional practices emotionally they are not ready to follow the directions prescribed for them. The result is gross nutritional disorders both in the mothers and children. The same trend is carried in the progeny till their death. Both the rich and the poor are landing up in the same hospital: the former due to over eating and the latter due to under-nourishment. The rich and the well-to-do eat a lot of ready-made greasy and processed junk food according to their taste and mood. They eat a lot of fatty, oily, non vegetarian food items and milk products like ice-creams and sweets. The rich vegetarians also eat food very rich in oil, fat and sugar. Though it is said jokingly that, "**the women of the rich families feed their men with all types**

of rich and over-nutritious food items till they become sick and then they look after them anxiously": there is lot of truth in it. It is indeed paradoxical the ways people behave in their food habits. The cycle of this paradoxical behavior in the food and nutrition goes on from generation to generation.

The poor eat hardly enough for their energy needs let alone for their requirements of protein, minerals and vitamins. For example the poor tribal people in Madhya Pradesh, Chhattisgarh and Jharkhand cook one persons requirement of rice in five to six times the amount of water and share it among all the family members with a little bit of chilly or salt to accompany it. Both among the rich and poor regular and sufficient amount of vegetable consumption is rare. The cereals and millets provide the people with energy while the pulses non-vegetarian foods give protein. But vegetables and fruits provide the 14 vitamins and 30 minerals which are equally important to energy and protein. The ill-effects of poor nutrition last for several generations or appear after several generations. Surveys have shown that most of the people do not have any idea of the human nutritional requirements in terms of the type of food items to be consumed depending on the availability of the food items from one's own farm or from the market. Those who purchase from the market, buy the cheapest food items in the minimum amount. For most people their aim is only to survive not develop.

The daily diet of every person should contain besides the energy foods (cereals, millets and tubers) and protein foods (different types of pulses and non-vegetarian foods including eggs) a minimum of 50 gram each of cooked leafy vegetables, root vegetables and vegetables other than roots and leaves. Besides these 150 gm of the three types

of vegetables, 50 gm of mixed fresh salad and 50 gm fresh mixed fruit salad are essential part of the regular diet. Thus everyone should consume daily in two or three meals a total of 250 gm of vegetables and fruits (in five items mentioned above) to provide the human body with 14 vitamins and about 30 minerals which govern millions of hormonal and enzymatic production and utilization functions in our bodies. Deficiency of one or other vitamins or minerals can lead to both physical and mental retardation or mal-functioning of both mental and physical faculties. **Remember primarily we are to eat what we need, not what we like. Remember also healthy food habit is necessary for a healthy body and only in a healthy body will there be a healthy mind; a healthy mind is required for a healthy human life as opposed to an emotional or irrational life.** Both over and under eating are harmful to health. A healthy diet is essential for a healthy population and only a healthy population can create and maintain a healthy environment and healthy environment is necessary for a healthy population and a healthy population is necessary for a healthy and vibrant nation.

All the cities, towns, industrial and non industrial human settlements should have an adjacent area where the solid and liquid wastes are treated in proper ways to produce electrical energy, organic manures and other useful materials. Every place should have an inbuilt waste recycling complex. Organic manures should be utilized to produce organic vegetables and fruits which should form major part of the diet of the people. Today the health of the people is becoming more and more dependent on the medical personnel and pharmaceutical companies. This dependency is increasing day by day because they are consuming food items according to their likes and dislikes and not according to their nutritional requirements. Human

beings need to lead a rational life not an emotional life of likes and dislikes. Emotional life is helpful and needed in various aspects of life but it should be supportive of the rational and scientific facts. Going mostly by emotional fluctuation in life is a threat to human race as well as to the environment in the long run. A well balanced diet should be the primary medicine for a human being. A rational approach to food consumption is the first step to mould one's mind and character. A well disciplined people only can maintain their eco-system in the proper way.

Twenty Third Law: Commercialization of food and sex degrades humanity and environment. Commercialized food known as junk food degenerates the physical and mental health of the people while commercialization of sex and womanhood degenerates social and moral life of the people. A rational human approach to food and sex is necessary for ensuring a healthy population which is a necessary condition to maintain a well-balanced ecosystem.

An emotionally charged hedonistic approach will only degenerate the human and eco-system. According to most religions, God set man as the master and ruler of the earth and everything in it. If the **master and ruler himself is sick and disoriented how can a healthy eco-system be created and maintained?**

Food and sex are interrelated in such a way that life is impossible without either of them. **Food is for preservation of life while sex is for preservation of humanity. Both are so sacred in human life that engaging in one or the other is a holy act.** Praying before food intake is a habit in most of the cultures, so too anything related with sex and procreation is celebrated as a sacred event in almost all the cultures. Food is offered to gods and a child is offered to gods in

almost all the cultures. Marriage is sacred and is celebrated in the temples or churches. There should be moderation in everything; so too in food and sex. Commercialization of food has lead to overeating by the rich minority while the vast majority and poor go hungry. **Commercialization resulted in over-eating and squandering of food items. Similarly commercialization of sex leads to prostitution, sex trafficking, sexual violence and desecration of womanhood itself.** Commercial sex is the main path way of spreading HIV and AIDS.

Look around; everywhere there is advertisement of all types of junk and ready to eat types of foods unusually wetting the appetites of the children and even the grownups. Most of them are processed foods adulterated with all possible taste and colour enhancers which are mostly made of harmful chemicals. Some of the processed foods are appetite enhancing and people who taste them once will feel like eating again and again leading to overeating and obesity which is one of the most serious health problems in the developed countries and among the rich people. Any casual observer will notice that their children are less healthy and prone to all kinds of physical and mental sicknesses. Many of them suffer from hormonal and mental disorders of various degrees. A large percentage of them are emotionally imbalanced and of unstable characters and even with criminal tendencies.

Food processing consumes a lot of raw food materials which otherwise would have been used by ordinary people. Food processing industry is enormously wasteful in the pretext of maintaining the best quality. Any processed food will be five to ten times costlier than the raw food items used for processing. Perhaps after the arms trade, food processing industry is the second best multinational

business arena. Food is the primary concern for any human being and hence processed food items are sought after anyone who can have access to it. The cost of all the processed food sold is many times the cost of its processing or production cost.

Similarly commercialization of sex is another area where man began to buy and sell sex and women in the open market. It has lead to commercial prostitution and sex trafficking. Women are reduced to one of the commodities in the market. Commercial sex is part of the tourism and entertainment all over the world. As result in spite of all effort the role and status of women in society is reduced to objects of enjoyment. Like over eating leads to health problem, over indulgence in sex enhances the incidence of sex related diseases. Commercialization of sex and women is a topic highly debated and discussed by people all over the world. They are very familiar with all harmful aspects of this evil practice and there is no need of discussing more about it.

Commercialization of both food and sex has lead to degradation of natural and human resources. Commercialization of food increases consumption and food wastage during eating. As already seen processing of food is wasteful and is an unjust act to the ordinary and poor people who are mostly lacking in sufficient food. Increased food requirement leads to the increased land area cultivation and utilization of unpaid or under paid labour leading to unjust and exploitative situation. Increased land utilization has lead to increased deforestation and soil degradation. Commercial farming leads to use of increased use of pesticides and insecticides which again contaminating the food products leading to new types of diseases like cancer.

Twenty Fourth Law: Both human existence and

development have to be taken care together. Human life has two main aspects: 1) Existence 2) Development. Of these Existence is prior to development. In human life, Existence without Development is meaningless; but Development without Existence is impossible.

Existence implies both physical and mental; development also consists in physical as well as mental. Every one aims to promote better and fuller human life both in existence and development. Implementing development programmes without ensuring proper existence of each individual or community is like building buildings without proper foundation. We have educational programmes without solving poverty. How can a child study with a hungry stomach or how can he apply himself to higher education if his mind is not properly developed due lack of micro-nutrients which are essential for the brain development and which is certainly lacking in the much popularized mid-meals in the schools where children come mainly for the mid-day meal. In most of the developing countries both physical and mental development, which is part of human existence is not taking place.

Even in the so called developed countries human existence is not in the ideal situation since they are consuming much adulterated junk food or go by undue likes and dislikes in food consumption and other life styles of comforts beyond the limit. That the physical and psychological ailments are on the increase is a clear sign that human existence is not in the way it should be. Everyone knows that too much of a luxurious life do not contribute to the proper existence of a human being for a proper developmental existence. Development is not merely amassing wealth and luxury items. What is the use of too much money and luxury if one does not have

a proper human existence? **The principle of "Tantum Quantum"** (a Latin phrase which means "so much as, in as much as, in so far as" **should be the golden rule of need application as well as limit application. "Everyone should have according to his need but one's need should not be encroaching upon the need of the other".** Aim to promote fuller Existence for everyone means trying to develop every one.

As already mentioned existence involves both physical and mental. Good physical existence does not ensure good mental existence. The rising crime and violence including wars based on ethnicity, caste and religion are signs of poor mental existence of an individual or community.

Twenty Fifth Law: Recycling of all solid and liquid or urban or rural wastes generated by people in industries, agriculture and domestic animals. All biological wastes can be converted into organic manure, bio-energy or commercially useful products while all non-biological or industrial wastes should be recycled into useful products. All types of plastics are recyclable into very valuable products. All domestic waste water is excellent for irrigation. It is high time that we follow the golden idea of "Waste is wealth" in our life.

At present most of the organic and inorganic wastes of domestic, agricultural and industrial wastes in most of the countries in the world are dumped into any place in a very unhealthy and wasteful manner in the open or into water bodies including the ocean polluting the environment. All the solid, liquid or gaseous wastes can be raw material for many useful products. Management of all types of wastes should be developed into a profitable industry both by public and private partnership.

Most cities in the world are situated on the banks of

the rivers and it was and is still common to drain all the city sewage into the river. Rivers Ganges receives not only the sewages from hundreds of big and small cities but also numerous dead bodies of humans and animals. So too all others major rivers and their tributaries. Any city sewage contains huge amount of liquid which when treated yield large amount of irrigatable water and small amount of solid organic manure. The cumulative amount of treated water in India would be sufficient to irrigate large tracts of farm fields; similarly the solid organic manure. Israel though a water scarce desert like country is an excellent example of recycling almost 90% of its domestic waste water for irrigation to produce tomatoes, carrots, turnips, grapefruit, and bananas, among others. Israel is also a significant exporter of dates, avocados, olive oil, pomegranates, and almonds, and it is a world leader in agricultural technologies especially reuse of domestic waste water. The same can be done in any country to boost up global agricultural production. However the industrial waste water including from the hospital complexes need special treatment to remove harmful substances before the liquid portion can be reused. At present technologies are available to treat and reuse any liquid or solid wastes from urban domestic and industrial areas. Pollution can be drastically reduced if all the countries follow the same. Maintaining a vegetable and fruit garden is an easy way of recycling the domestic waste water at each household level. Planning to recycle all domestic and animal shed waste water at the household, village, town and city level is one of the important form of environment management.

Twenty Sixth Law: Promote peaceful co-existence with nature and PEACE MODELS. Humans should lead a Peaceful Co-existence with nature and promote Popular Environmental Agronomic Community Education to

Mobilize and to Organize to Develop Environmental Living Systems (PEACE MODELS).

Humans on earth are the end product of the millions of years of evolution and are still evolving though an individual human may not realize it. That he is the product of the nature and is governed by the laws of nature in his growth and development is a fact that he has to reckon with. Yet the humans are the masters of the earth and everything in it and yet they are the most vulnerable of all the living beings on the earth. All the major components in the nature such as soil, water, air, light, heat, microbes, plants and animals are though at his disposal he should not and cannot use them as he likes. He should preserve them and use them judiciously so that the future generations also will have the same things in sufficient quantity.

In the **PEACE MODEL** system there is a physical and mental aspect which in fact cannot be separated existentially though logically we can make distinctions and definitions. The physical aspect consists in adhering with the above mentioned commandments of the Nature whether one is involved directly or indirectly in the Nature. The mental or spiritual aspect of the PEACE MODEL is a sense of affinity, unity, oneness, empathy to all the creatures in the nature. It is also a conviction that at the ultimate level there is a oneness and inter-relationship between all the things in the Nature. This mental affinity is not without physical basis. At the ultimate elemental level all the things in this world are made up of the same matter but different in structure, composition and functions as we find in the microbes, plants, animals and humans. Everything comes from the earth including the atmosphere and everything goes back to the soil or to the earth. It is amazing how different are each and every microbe, plant, animal and human on earth and yet they are composed basically of the same material.

Beyond the physical we feel an affinity towards plants, animals and other human which we can clearly experience. How an animal will responds to a human and how even a plant responds to a human are facts experimentally proved. How each and every one of them contributes to the life of each human being on earth is an awareness every human should cultivate and cherish. People who live in PEACE MODEL system will feel an affinity to the soil on which they walk, cultivate, build their houses, in their compound; sometimes they handle it for various purposes like making a pot or other an artifact, or prepare it for planting a flowering plant etc. Similarly he will feel an affinity to the water he drinks and with which he washes, baths, cleans, cooks, irrigates, draining the wastes from the body, house, street, city etc. In the same way he will feel the air he breaths in and out and realize the oneness with the atmosphere. He will realize how the sun light is a major factor for his physical and mental development and a child kept in darkness will be deficient in many ways. He will realize that a specific temperature is a critical factor in the life of a human being. In many religions sun is worshiped as the ultimate source of heat and light. Further he will have a realization that his body is full of millions of microbes inside and outside his body doing many beneficial roles in the body like digestion and excretion. He will realize the contribution each plant is doing for the welfare of human life by way of generating oxygen, producing various types of food, fuel, fodder, fiber and fabricating materials. Finally he will realize how various types of animals are contributing to his life by way of cheap labour, food, fibre, transport, industrial raw materials etc. Finally how each human being exists in inter-relationship with each other.

All these types realizations will make him grateful to each and every component in the Nature. He may express these oneness and relationship in the form prayer,

meditation or contemplation and mystical experiences. It may be expressed in writings of articles and poems, dramas, paintings, plays etc.

A true PEACE MODEL human will get involved in the Nature like gardening to produce three types of vegetables, fruits, herbal plants for medicines and herbal chatney. Onion, garlic and leeks are essential items in any cooking. They can be prepared by one in pots or in beds on the land around the house, on the balconies and on the terrace of the house. At least one can get involved in the Nature in producing the different leafy vegetables, rood vegetables and others vegetables like pods, stem and immature pods and fruits. As far as possible produce some things of what you daily use instead of completely depending on the market or on the others. Similarly people can get involved in the production of meat, egg, milk and other products they use. Thus a PEACE MODEL man will spend at least 20 -30 minutes a day in the production of some of the basic things he needs.

Another aspect of his PEACE MODEL living will be to dispose the waste materials from his habitat by recycling, processing into products for recycling. At present most humans do not want to touch the soil. It is considered a menial labour to get in touch with the soil. In Hinduism there is a staunch sense of Brahmanism not to touch the soil and wastes. But the present city dwellers are more Brahminic than the Brahmins themselves. The children in the city do not know that the cows and buffaloes give us milk, give us wool, meat, fat, guts, hair etc. For them all the things needed are purchased from the super market. A PEACE MODEL human will get involved with elements of nature to produce at least something of what he needs daily.

Last but not the least a PEACE MODEL man will care for the buildup of the environment in planting and caring

for trees to forest or reforest the barren and mountainous areas, common and uncultivable lands of his habitat whether city or village. He would even go out of his habitat to take up or involve in the tree plantation or pond or irrigation or drainage construction etc. without expecting any remuneration. He will thus be a contributor to the environment build up as well as an active participator in the productive enterprises of the nation.

Conclusion

These twenty-five commandments or laws of nature are enunciated after considering many aspects of human and environmental existence and development on earth. They are points for study discussion and debate. There are several points that the policy makers and planners at the international level need to understand and act upon. Mere declarations and celebrations at the international and national level are not useful; we need planned concrete result oriented action programmes in environment management.

Some of the points mentioned as the laws of nature may be controversial and may generate a lot of heat and dust in the discussion and debate, as people all have their own ideas about environment management. Yet after all the heat and dust raised some will find the truths behind those enunciations of laws and consensus will hopefully emerge.

Everyone has to realize that generations of people and animals will go by but the land has to remain intact to sustain the future generations. It is every one's responsibility to maintain sustainability of the land and water resources intact and safe. Finally the PEACE MODEL need to be emphasized; should be inculcated by everyone and should be put into practice.

Chapter-02

Basic Ecological Concepts and Concerns

Ecology, Eco-system, Environment, Forest Eco-system, Agro-eco-system, Human Habitat Systems, Industrial Eco-systems are some of the main ecological concepts important to every human being and to researchers and developmentalists using the ever increasing knowledge and technology: all contributing to the effective management of human environment.

1. Ecology coming from a Greek word ***oikos***, with its original meaning as an extended family unit, that consists of the house, members of the family, slaves/workers, farmland and all the properties and their interrelated and interdependent relationships between them. Ecology deals with the relations of organisms to one another and to their physical surroundings. In its broadest sense it means the science of Eco-system. Science is a systematically organized body of knowledge on a particular subject at the level of intellectual and practical endeavour encompassing the systematic study of the structure and behavior of things in physico-chemical and biological world through observations and experiments expressed in scientific terms and are applicable in practical and profitable programmes and projects. Science encompasses any type of study and innovative research in any topic. Every field of research and development using the ever-increasing knowledge and technology adds to the volume of science and technology. Hence all aspects of scientific studies come under the

ambit of Ecology. Though the term is new it is an **umbrella science** for all other subjects we used to consider them as science subjects.

2. Ecosystem simply means a household system and here it refers to the whole earth, sun and other planets in the solar system and their moons. However ordinary humans have direct involvement at present only with the earth and everything in it are considered members of a household comprising of all **non-living** and **living components.** The broad categories of **non-living components** are different soil types, angle or degree of slopes of the land surface, water in its three stages of its existence, air as a mixture of different gases and their varying degrees of concentrations, sun light a combination of seven coloured wave lengths, heat with its variations in temperature and radiation. Among the **living components** are an estimated one trillion types of micro-organisms, forming the base for all the living components of our household eco-system, followed by about 3,74,000 plant species and about 8.7 million animal species and 7.8 billion humans (2020). All the major components of the eco-system exist at the visible and invisible levels too. There should be a balance between and among all the nonliving things and the living things for the sustainable existence of our ecosystem the mother earth.

At the visible level all the living and non-living components in our Eco-system are organically inter-connected, inter-related, inter-dependent and are in a dialectical and evolutionary process at multiple levels of their existence and development as demarcated by the double edged arrows in the following diagramme (Fig 1). The double edged arrows signify the **inter-relationships** and **inter-dependence**.

Any casual observer can understand the nature of the outer circle of six categories of nonliving components encircling an inner one consisting of three gradationally existing and responding living components. It is further revealing to note that the centre of all is the human being gifted with the highest known level of intelligence, imagination, memory, capacity for estimating, computing, planning and executing capacities and above all an urge to make progress by inventing more and more, newer and innovative, faster and better ideas and theories evolving effective and efficient instruments in his way of thinking, planning, communicating and executing. M**an is the centre and master of the eco-system.**

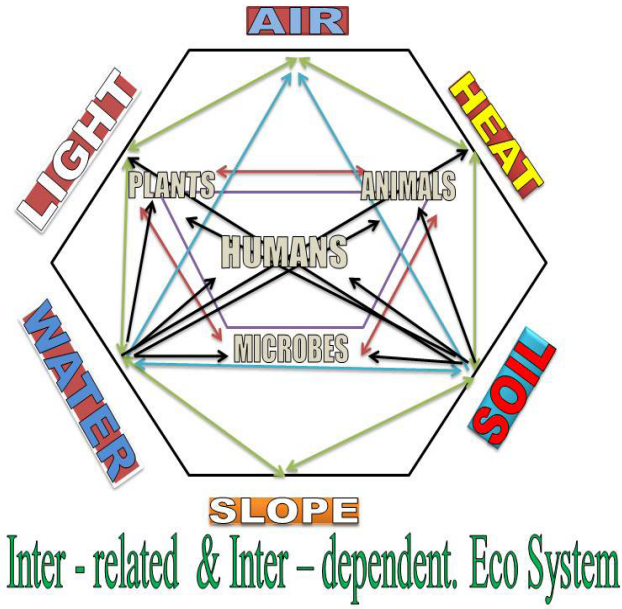


Fig 1: Eco-system Diagrammatical Depiction

At the invisible level all these components in the above given diagramme are composed of chemical compounds composed of 118 elements including 30 radioactive elements as can be seen in many versions of periodic table given as follows in Fig 2. Now we also know that nonliving components are composed of inorganic compounds and the living components are composed of organic compounds.

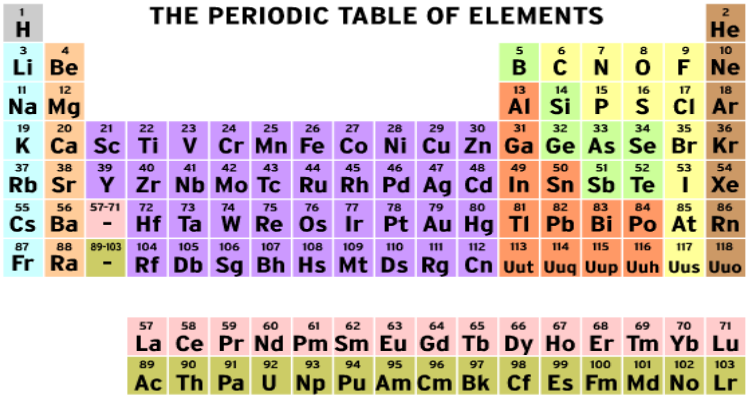


Fig 2: The Standard Periodic Table

We also know that various compounds consist of the many of the elements given in the Fig 2. exists at the subatomic levels too and already 17 of them are known to us as show in Fig No 3; but in Fig 4 the number of subatomic particles has gone up to 30 counting the anti-matter particles also. Science may discover further many more **sub-sub atomic particles** which **may be** the composition of the matter and the space**,** the subtle-most underlying substance of everything in the universe (as mentioned in the first line of **Gayatri Mantra**: ***Om Bhur Bhuvaswaha***). This ***Bhur*** may be denoting the most elementary and subtle-

most of the particles, even beyond what is shown in Fig 3 & 4. *Aakash or* Space may be the subtle-most, primordial and eternally existing evolving substance (*Bhur*) in which everything else may be existing or from which everything may have been evolved from subatomic particles to atoms followed by inorganic and organic compounds and further into millions of microbes followed by micro and macro plants and then to the animals and humans over a period of billion and trillions years.

Now we all know that ultimately everything visible and invisible in the universe can be reduced to the cosmic principle which is an eternally evolving and expressing energy embodying itself in every visible and invisible forms of beings on the earth our eco-system and in everything in the universe.

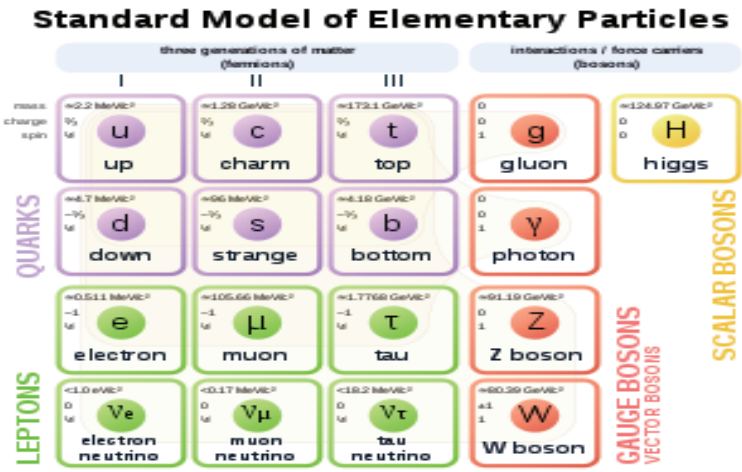


Fig 3: A Chart of Sub-atomic particles

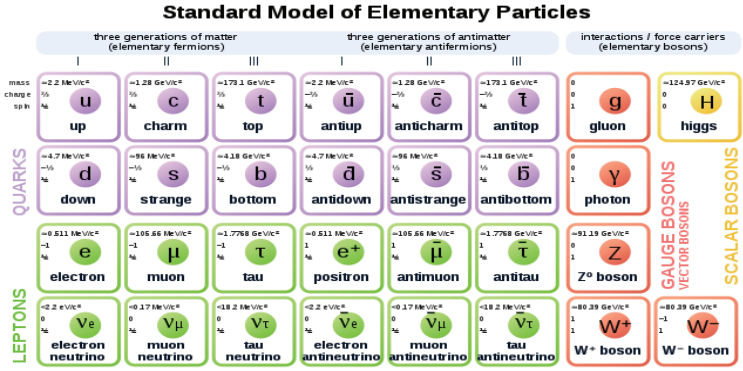


Fig 4: Recent Chart of Sub-atomic particles including antimatter

The second chart of sub-atomic particles (Fig 4) is given to show that as time goes on science is discovering more of the **sub-atomic forms of particles of matter and antimatter**. The European Organization for Nuclear Research, known as CERN, (Conseil Européen pour la Recherche Nucléaire", or European Council for Nuclear Research) is an organization that operates the largest particle physics laboratory in the world. Established in 1954, the organization is based in the northwest suburb of Geneva on the Franco–Swiss border and is an endeavour of 23 member countries. Some of the subatomic particles like "Xi_b'- and Xi_b*-" are six times more massive than protons: who knows this may give a lead to dark matter which is so heavy. The latest of the sub-atomic particle Higgs boson was discovered at CERN in 2012. We can be sure that more of such elementary particles will be discovered by the scientists of future generations.

According to Indian thought everything is composed of **earth, water, air, fire and akash of which Akash is the most subtle substance of the matter. Akash still remains**

an undefined term though it may be translated into space or ether with equivalent words like cosmos, firmament, sky, space, celestial etc. In the Western philosophy there is the distinction between **matter** and **form.** Again in Indian thought there is the distinction between **gross** and **subtle** forms of matter. In science all these concepts are analogical and analytical but not absolute, leaving room for further insights and discoveries. In short matter exists in an infinite range of energy forms, even in forms not yet detected. **Energy Forms are in the matter and matter is in the energy forms. Hence all the components of the Eco-system exist in particles of matter and energy-forms, in which matter is visible and energy form is invisible but becoming sensible to sophisticated instruments and complex mathematical equations.**

Contemplating on such a complex, timeless combination of matter and energy forms in the successive evolutionary events, one will automatically break into a prayerful self-expression/exclamation like **"Om the Eternally Evolving and Expressing Energy, Embodying itself in every being in this Universe (E^6)."** The discovery of elementary particles shown in Fig 3 & 4 indicates possibilities of discovering further and more subtle particles of matter which are always in a process of continuous evolution**. EVOLUTION implies also births of generations of things in the universe, from sub-sub atomic particles to the giant stars and galaxies. It also implies DEVOLUTION implying deaths of generations by which everything evolved disintegrates back into its original or ultimate forms of sub-sub atomic particles or akash. It may also indicate the possibility of a continuously CONTRACTING and EXPANDING (disintegrating and integrating) universe resulting into the formation of newer universes one after the other in a timeless evolutionary process.**

All particles of matter are charged and are under various forces like gravitational force, cohesive and adhesive forces, magnetic and electric charges, centripetal and centrifugal, speed and acceleration, etc. **Einstein's equation $E=mc^2$** means everything in the **Eco-system** is an expression of various forms of energy acting and interacting with each other and is in an **invisible evolutionary dialectical process,** some of which man is able to control and guide while others still are not. **Hence management of eco-system means management of some of the visible and invisible components of the earth our eco-system. The term Eco-system therefore also refers to all the visible and invisible, living and nonliving beings and their complex interactive relationships between them. Ecology also means the knowledge system or science developed on these interactions of the components in the eco-system at the atomic and subatomic level.**

Humans are not able to see the air and microbes; but he can feel the moving air at varying speed or intensity. For thousands of years humans had no idea of microbes; but today he is able to observe them through microscopes of various sophistication and has already developed a system of knowledge called microbiology which is the study of microbes like viruses, bacteria, archaea, prions, protozoa, fungi and algae. We have already decoded the genetic codes of almost all the micro-organisms present in the world.

3. Environment

Environment refers to the surroundings of any living being individually or in groups at the visible and invisible levels. The surroundings may be living or non-living, visible or invisible, proximate or remote, animate or inanimate, plants or animals, aquatic or non-aquatic, metallic or non-metallic etc. Hence we refer to the environment of humans,

animals, plants and microbes. We can say the environment of a single person or a group of persons, similarly of an animal or animals or a plant or plants or microbe or microbes. With reference to one or a group of the living beings all other living and nonliving beings constitute its or their environment. Every living being is able to influence on its environment and at the same time an environment also influences a single or a group of living beings: influence is mutual. But humans are able to influence more on his living and nonliving environment: hence he is considered the **master of his environment**; he can modify his environment to a great extent. For thousands of years, humans have modified the physical environment by clearing land for agriculture or damming rivers to store and divert water for agriculture or production of electricity. For example, when a dam is built, less water flows downstream. This impacts the communities and wildlife located downstream who might depend on that water. Such impacts may be positive or negative. We shall have several other chapters to describe the management practices of various components in the environment.

4. Forest eco-system

The FAO/UN description of a forest is worth mentioning. "A forest is defined as a land with a tree canopy cover of more than 10 per cent and an area of more than 0.5 hectare Forests are determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5 m. Young trees that have not yet but are expected to reach a crown density of 10 percent and tree height of 5 m are also included under forest. The term includes forests used for purposes of production, protection, multiple-use or conservation (i.e. forest

in national parks, nature reserves and other protected areas), as well as forest stands on agricultural lands (e.g. windbreaks and shelterbelts of trees with a width of more than 20 m), and rubber wood plantations and cork or oak stands. The term specifically excludes stands of trees established primarily for agricultural production, for example fruit tree plantations. It also excludes trees planted in agroforestry and social forestry systems. Forest includes natural forests and planted forests."

According to 1952 and 1988 Forest Policy of India we are supposed to maintain 66.6% of the hilly areas and 33.3% of the plain areas under forest cover. The Ministry of Environment, Forest & Climate Change of India defines 'forest cover' as "all lands, more than one hectare in area with a tree canopy density of more than 10%", and 'tree cover' as "tree patches outside recorded forest areas exclusive of forest cover and less than the minimum mappable area of one hectare." The forest area defined according to FAO is "land spanning more than 0.5 hectares with trees higher than 5 metre and a canopy cover of more than 10 percent, or trees able to reach that height in situ (difference is only in the area: FAO/UN is 0.5 ha and India is one ha).

Both the FAO/UN and Indian definition of forest is far too below the ecologically required standard: half a hectare area of forest will have no impact on the climate or water and soil conservation nor a one hectare area according to Indian standard; both do not specify whether it is perennial forest or temporary forest; temporary forests have no impact on the environment; large areas of perennial forests on the hill tracts above 33.3% slope only will have significant impact on various environmental factors; in fact all the land areas above 33.3% slope should be under perennial forest cover;

if a country is having only areas above 33.3% then the whole area should be under forests and no cultivation or animal husbandry practices should be allowed; similarly a minimum of 66.6% area of a country should be under perennial forests irrespective of the percentage of slope; that means even if country is a completely leveled land, still it should leave a minimum of 66.6% of the area under perennial forest; all countries should maintain a minimum of 66.6% of the area under perennial forest though the ideal would be 70 percent; forests should harbor all types of flora and fauna related to the agro-climatic conditions of the locations.

Forests regulate steadiness of agro-climatic and aquatic ecosystems into an ecological balance, protect biodiversity, play an integral role in the carbon dioxide and oxygen cycle, produce and add organic matter to the soil, support human and animal life systems. The forests absorb Carbon dioxide from the atmosphere and release oxygen in return while producing carbohydrate. The carbon in the carbohydrate remains stored up in the forest biomass, but can be released into the atmosphere when any part of the forests is burned. Trees in the forest maintain humidity by the process of evapo-transpiration and this humidity gets combined with the water bearing clouds coming from the sea and other water bodies create optimum humidity to cause rainfall. The latitude and height of the terrain determines the temperature range in the climate.

Both ocean and forest play similar role in regulating the climate and their effect on climate is directly proportionate to their area coverage on the surface of the earth. The oceans cover about 70% of the earth's area; hence the area coverage of forest on the land area is supposed to be 70% including all the area above 33.3% or 1:3 ratio of rise to run

slope because at this slope there is sufficient angle of repose for the minimum agricultural and animal husbandry land use pattern. At least 66.6% of the land area should be under forest cover to maintain the ecological balance. At the world level (UN & FAO) minimum limit the forest cover is fixed at 33.3% of the total area irrespective of the degree or percentage of the slope of the land. **Slope which is key factor in determining the soil stability does not figure at all in the global environmental concern: soil stability is the most important pre-requisite for the environmental stability. It is indeed a very serious omission. The countries may be politically free to decide their own forest policy and the minimum required forest area but they are not free from the ecological imperatives.** The percentage of forest cover ranges from 0.07 to 89.0 percent among the 192 countries maintaining the record of their forest cover: only 19 countries have forest cover above 65 per cent of their geographical area.

5. Agro-eco-system

Agro-eco-system refers to involvement of humans in that part of the eco-system where agriculture, animal husbandry and inland aqua-culture are practiced to generate all his needs like food, fibre, fodder, fabricates and pharmaceuticals for his **existence and development** and signifies the interactive and interdependent relationships between soil, land slope, water, air, light, heat, microbes, plants, animals and humans as in a household as shown in Fig 1. Among them slope of the land is a major determining factor in the management of the agro-eco-system. Globally it is estimated (FAO/UN 2019) that about 50 per cent of the habitable land area on earth is under various agricultural and animal husbandry practices to produce food for humans and fodder and feed for animals to produce

milk, meat, wool etc. Management of agro-eco-system has to follow the land use pattern laid down respective of country's land use laws and regulations. The global land use pattern as assessed by FAO/UN is given in Fig 5. Of the total surface area of the earth only 29% is land and 71% ocean; of the land 71% is habitable land 19% is barren and 10% is under glacier; of the 71% habitable land 50% are agricultural, 37% are forests, 11% are under shrubs and one percent each are under urban built up land and fresh water; of the 50% agricultural land 77% are under livestock rearing and 23% are for crops. However 82% of the calorie supply is from crops while only 18% is from animals; of protein 63% is from crops and 37% is from animal source. There are imbalances in the use of land for livestock and crop farming in comparing with the availability of protein to humans in percentage. Such imbalances affect the agro-eco-systems.

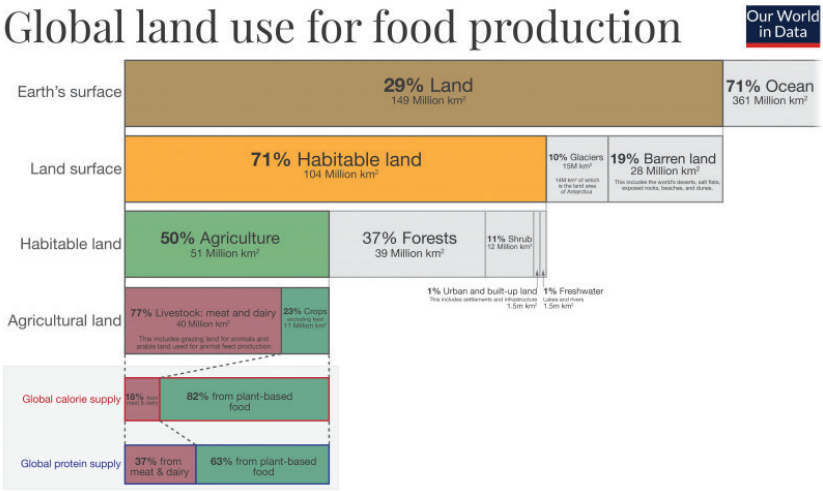


Fig 5. Global Land Use for Food Production (FAO)

Converting most of the above data into hectares (1 Sq.km =100 hectares) we have the following:

Total surface area of the earth	510 million sq.km	=	51000 million hectares
Total sea area	361 million sq.km	=	36100 million hectares
Total land area	149 million sq. km	=	14900 million hectares
Habitable land	104 million sq.km	=	10400 million hectares
Glacier cover	15 million sq.km	=	1500 million hectares
Barren land	28 million sq.km	=	2800 million hectares
Agriculture	51 million sq.km	=	5100 million hectares
Forests	39 million sq.km	=	3900 million hectares
Shrubs	11 million sq.km	=	1100 million hectares
Urban built up land	1.5 m sq.km	=	15 million hectares
Fresh water area	1.5 m sq.km	=	15 million hectares
Livestock	40 million sq.km	=	4000 million hectares
Crops	11 million sq.km	=	1100 million hectares
Calorie from animal source is		=	18 per cent
Calorie from crop plant source is		=	82 per cent
Protein from animal source is		=	37 per cent
Protein from crop source is		=	63 per cent

Total Population of the world 7.8 billion in 2020 projected to be 10.00 (9.9) billion in 2050

It is to be noted that there is undue imbalance in the land use pattern for agriculture and animal husbandry: while 82 per cent of the calorie and 63 per cent of the protein are available to humanity from the crops, the land allotment to animal husbandry is nearly four times that of the agriculture: clearly a case of gross imbalance in the land use pattern.

6. Human habitat systems

The human habitat systems include areas under villages, towns, cities, areas under factories or production centres, institutional areas, sports and recreation complexes, areas under roads and railways, aerodromes, shipyards, etc. From the middle of the last century migration of people from the rural agricultural areas to the urban areas are taking place in search of livelihood. It is estimated that currently (2020) some 56.2% of the world's population numbering about 4.4 billion inhabitants live in cities. In 1950 about 2/3 of the population worldwide lived in rural settlements and 1/3 in urban settlements. By 2030 we will observe roughly the reverse of this distribution, with more than 6 billion people living in the messy, burgeoning atmosphere of urbanized areas (Fig 6). By then it is expected that there will be about 1400 cities in the world with population above 5,00,000 population. By 2050 the ratio of urban to rural population is expected to reach 70:30 because by then 80% of the global GDP generated will be in the cities with corresponding decrease in the agriculture and animal husbandry sector. There will be massive movement of people from the rural agriculture and animal husbandry sector to the urban production and business centres. Such phenomenal growth will create unprecedented ecological problems and challenges. Urban waste management, both solid and liquid will be one such problem besides resource crunches of all sorts.

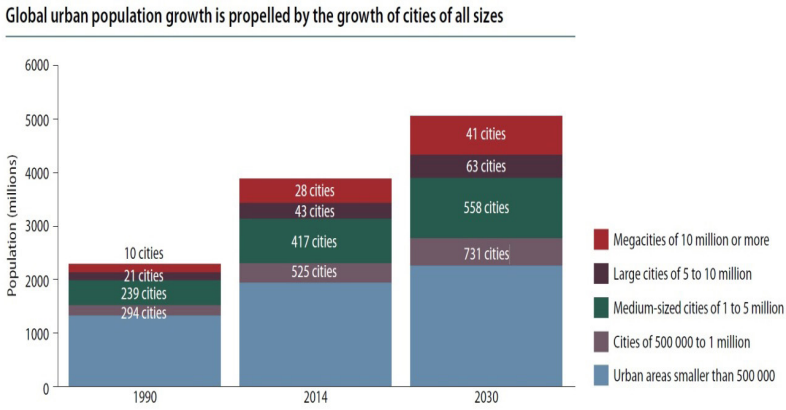


Fig 6 Population Growth in the Cities

7. Industrial eco-systems

Presently no environmentalist can bypass the impact of accelerated Industrialization taking place all over the world. Both industrialization and urbanization seem to go together hand in hand though historically four stages of industrial revolution can be distinguished:

The first stage: began in year 1765 and was characterized by the rapid mechanization which drew people from agriculture sector to industry which became the back born of the economy of most of the countries. Coal and steam engines played a key role to speed up the manufacturing of railroads for massive transportation to boost the economy.

The second stage: began in 1870 almost a century after the first. It started with several massive technological advancements supported by the discovery of electricity, gas, and oil which became the main forces behind the second industrial revolution marked by steel manufacturing, synthesis of chemicals, improved communications and transportation by automobiles, trains, ships and airplanes.

Third Industrial Revolution: began in 1969 the second half of the 20th century. The third industrial revolution was marked by inventions of nuclear energy, electronics, telecommunications, computers, bio-technology and space explorations. The new technologies opened the doors to research and development of programmable logic controllers (PLCs) and robots leading to greater level of automation.

Forth Industrial Revolution: Located somewhere between the end of 20th and the beginning of 21st century the 4th industrial revolution was marked by globalization and accelerated activities in the world of human communication, finance, commerce, movement of goods and services from anywhere across the world within no time blurring of boundaries between the physical, digital, and biological worlds. It's a fusion of advances in artificial intelligence, robotics, the Internet, 3D printing, genetic engineering, quantum computing, and other subtle technologies. It is the collective force behind many products and services that are fast becoming indispensable to modern life. Think of GPS systems that suggest the shortest route to a destination, voice-activated virtual assistants such as Apple's Siri, personalized Netflix recommendations, and Face Book's ability to recognize your face and tag you with a friend's photo. Programmes and projects can be implemented from anywhere to everywhere in the world helping people to take advantage of the marvels of the fourth revolution in their everyday lives. Digitalization, computerization and telecommunication revolutionized every sphere of human life: manufacturing, commerce, banking, entertainment etc. Humans have already entered into a world of complex cyber systems and virtual reality; what next is not a question but an unpredictable reality and

transformative changes. Figs 7 & 8 are included to trigger your imagination to expect what is in the future that is going to affect our world or solar eco-systems?

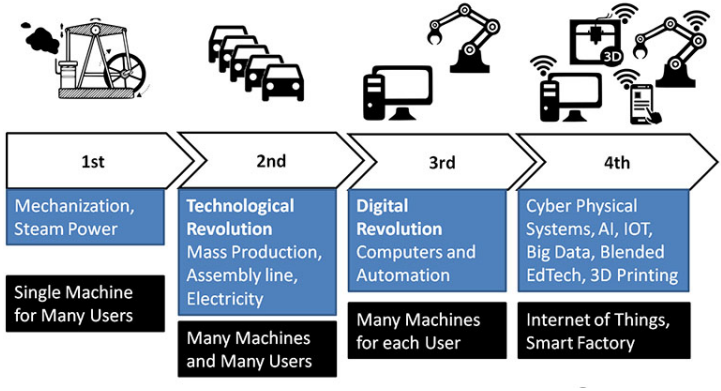


Fig 7 Stages of Industrialization

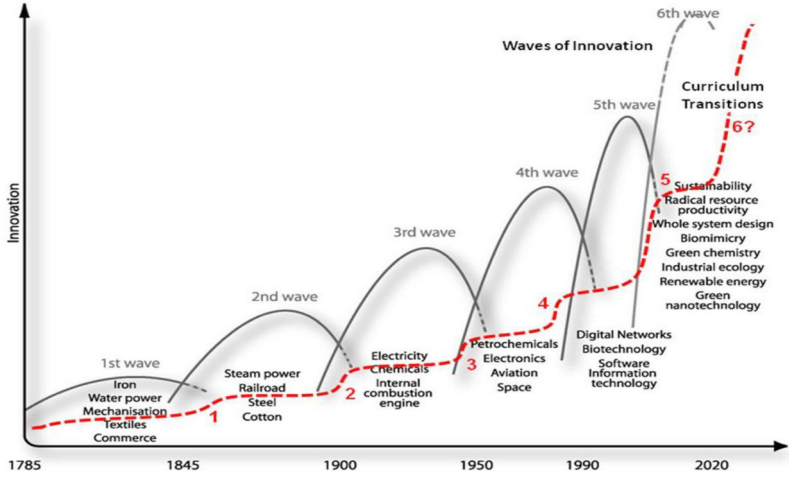


Fig 8 Further Waves of Innovation

Future Waves of Innovations

Fig 8 already gives a hint to the future innovations. Some are of opinion that the 5th and 6th waves have already started; others are of opinion that hereafter there will be waves or stages of innovations of multiple cybernetic technologies which will dominate all spheres of human life like cyborgs (Fig 9) of the type we may never be able to imagine.

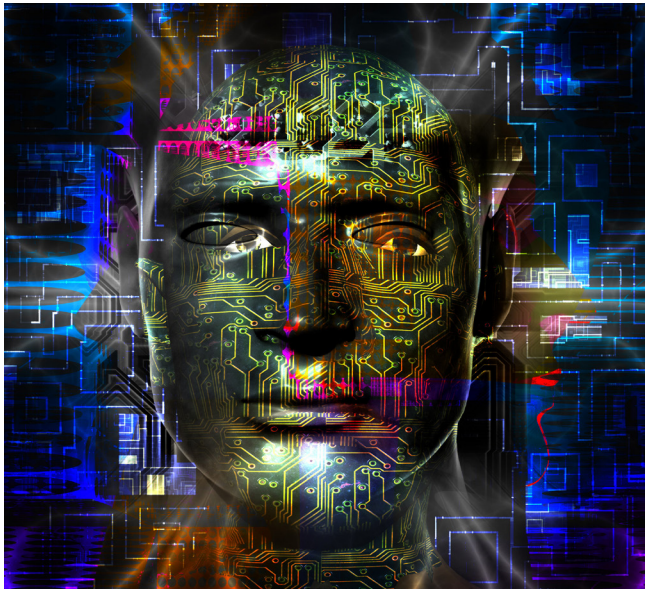


Fig 9. A Model of Cyborgs

In future it will not be stages of industrialization but a merging of different branches of cybernetics and cyborgs. By that time the population depending on agriculture, animal husbandry and other land based production systems will be reduced to minimum and the urban population will be at the maximum level. **The humans themselves will be undergoing changes both physically and mentally which may be beyond our imagination.**

Will our descendants be cyborgs with implants of hi-tech cyber programmes, regrowable limbs and cameras for eyes like something out we hear in science fictions? The humans might morph into a hybrid species of biological and artificial beings? Or could we become smaller or taller, thinner or fatter, or even with different facial features and skin colour? Though these questions seem fictional, when we scan the whole spectrum of human history they seem to become a reality. The 3D printing, or additive manufacturing, is the construction of a three-dimensional object from a CAD model or a digital 3D model.

Mere biological spectrum of a million years show that humans evolved tremendously from over millions of years period from *Homo heidelbergensi*s, which shared similarities with both *Homo erectus* and modern humans, but more primitive anatomy than the later Neanderthal.

Over the last 10,000 years of we have lot evidences human changes physically and mentally leading to explosions of knowledge systems and inventions increasing the human potential individually and collectively to achieve never-ever imagined things like information explosion through even-increasing applications of cyber-neuro sciences and technologies and their applications: as may be shown in the following figures (Fig 10 & Fig 11).

Fig 10: Will technology affect our evolution? © Donald Iain Smith/Getty

In the future sight and perception will not be a question of biological but a cyber-technological as Fig 11 indicates.

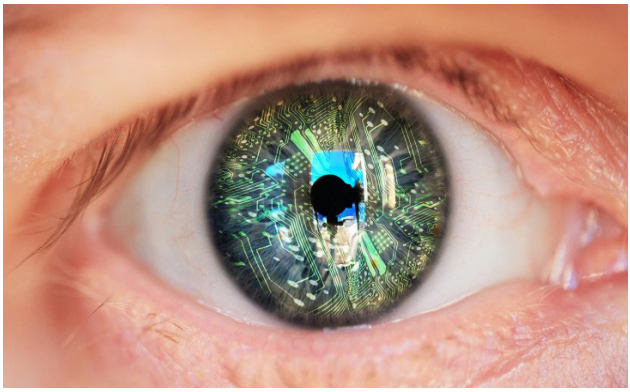


Fig11: Cyber-eye: © Daniel Haug/Getty

"There are enough indications to conclude the humans of the future will be more implanted than biologically evolved. Currently, people have physical implants but in the future implants will be to improve

the mental functioning to see the unseen, to hear the unheard, to imagine the unimaginable, to do the impossible, to actualize anything unimaginable, to evolve a new genre of neuro-cyber humans. The distance will not matter, transit will be momentary and humans will be multi-functional: time and space will merge in humans and in his environments. We already heard of designer babies; scientists already have the technology to change the genes of an embryo; perhaps humans will look like what their parents want them to look like. Natural selection will give way to artificial selection; "What we do with breeds of dogs, we'll do with humans" said Mailun. Will that bring environmental and human problems? We have to wait and see." (Source internet)

"Predicting out a million years is pure speculation, but predicting into the more immediate future is certainly possible using bio-informatics by combining what is known about genetic variation now with models of demographic change going forward," says Dr. Jason A. Hodgson, lecturing on Grand Challenges in Ecosystems and the Environment. **We can't exactly predict how genetic variation will change "**If humans colonize Mars what would be the evolutionary transformation in him? We don't know, but, certainly, human genetic variation is increasing along with increase of human capacity in geometric proportion. Worldwide there are roughly two new mutations for every one of the 3.5 billion base pairs in the human genome every year, says Hodgson which is pretty amazing and makes it unlikely we will look the same in a million years."

NB. Indebted to internet for Figures 2-11

Chapter - 3

Ecological Constants and Constraints

In the previous chapter we were introduced to different existing and future possible ecological systems. In this chapter we shall see the ecological **constants** and **constraints** at the world level and at Indian continental level. The same will be applicable to many other countries in the world to maintain the ecological balance at an above average level. To us the humans who are managers of the earth-eco-system, the knowledge of the constants and constraints of our eco-system is very important in planning and implementing all the ecological development activities.

I. Ecological Constants

Humans mainly engage themselves both on the surface of the land and on the sea and can make an impact on them temporarily or permanently but at present his impact is more on the land than on the sea. He can make drastic changes on the land area mainly for his economic advantages. But because of the law of **constants in the nature** he should not do anything as he likes on the land area or in the sea; nature maintains certain restrictions beyond which he is not supposed to intervene.

Constants

Ocean-Water and land ratio on the surface of the earth: On the surface of the earth 71% of the areas is covered

with water/seas and only 29% is the total land area. Let us give one per cent margin of error and make the **ratio as 70:30** for the easy estimations in future planning. This ratio is immutable and humans cannot do anything significantly to change it. That this natural ratio of sea and land area (70:30) is so important to maintain the ecological balance of the earth-eco-system can be best understood when we understand the **roles of the oceans** in maintaining the ecological balance of the ten major components (soil, slope, air, heat, light, microbes, plants, animals and humans) of the eco-system presented in Fig 1 in the previous chapter. Perhaps slope is the only factor which may not have any significant effect on the oceans and vice a verse.

Roles of the oceans

a. Oceans play a great role in regulating the annual seasons and climate variations,

b) Ocean currents play an important role in distributing warm water and air from equatorial regions to North and South Polar regions,

c) Ocean currents are important to all sea life as they regularly carry nutrients and food materials to organisms that live permanently attached to some specific areas in the ocean,

d) Ocean currents transport reproductive cells and ocean life to other places where they undergo fertilization, hatching and rearing of the young ones before they are dispersed into the vast oceans,

d. Ocean is a **sink of CO_2** maintaining **Oxygen-Corbondioxide ratio** at an optimum level in the atmosphere,

e. Oceans are rich in bio-diversity which are to be maintained at its full potential,

f. They are a great source of food including sea weeds for humans and animals,

g. They are great means of transport at massive level across the world,

h. Most of the holiday and health resorts are located along the seashores,

i. Seas provides huge employment: fishing to about 56 million people; subsidiary employment: like handling, processing, storing, distribution etc. to about 660-880 million people,

j. They are the common property of all the nations beyond 22 km from the shore,

k. Oceans are great source of salts, minerals and petroleum and great oil reserves in future,

l. In general oceans play the main roles of **Conserving, Protecting & Restoring all the components of the earth-eco-system (Fig 1) except perhaps the slope factor.**

Ratio of forest and non-forest area on the land

Unlike the ocean the forest area on the land surface is not fixed by nature; humans have taken possession of the whole land area, which originally was a forest, for his various economic advantages to the extent of destroying majority of the forest cover. In order to make an estimation of the optimum percentage of forest cover required on the land surface for maintaining the ecological balance, we need to understand the roles and functions of the forests on the surface of the earth in general and on the land in particular. The functions and roles are listed as follows.

a. "Forests are the lungs of the earth" maintaining the carbon dioxide-oxygen exchange in the atmosphere

maintaining their optimum ratio of 0.04 and 20.95 respectively,

b. Combining with oceans forests play a great role in regulating the annual cycles of seasonal & climatic variations,

c. The temperature in the forested hills is lower; forests and height of the hills and mountains are temperature regulating factors,

d. The evapo-transpiration from the forest area maintains atmospheric humidity facilitating rainfall in the hilly forest areas,

e. Forests play an important role in maintaining the water cycle on the land system, rain in the hilly forest areas maintain the springs, streams and rivers active throughout the year,

f. They preserve the top soils rich in humus formed by the decomposition of materials of plant and animal origin facilitating the growth of micro and macro flora and fauna,

g. They facilitates the inorganic and organic matter cycle on the earth,

h. They act as a store house of bio-diversity including medicinal plants,

i. Forests serve as a source of various types food items of animal and plant origin,

j. They also provide fodder for animals but free grazing is dangerous to forest system,

k. Forests are good source of fuel wood but only collection of dry wood should be permitted, no cutting of any live tree should be permitted,

l. Forests support sericulture, apiculture, lac insect

culture and provide Tendu leaves, Sal seeds, Sandal wood, medicinal plants, fibre, cane and bamboos,

m. forests provides raw material to several industries like timber, paper, plywood, rayon,

n. They provide employment opportunities to many people in various forest activities,

o. Forests are the abode of aboriginals or indigenous people of about 5,000 cultures,

p. Forest resources are a source of foreign exchange for any country,

q. They play an important role in reducing atmospheric pollution,

r. forests provide protection to rich variety of wild life both flora and fauna.

NB. There may be few more points to add on the roles of both oceans and forests. Each of the above mentioned points on oceans and forests could be topics for detailed study for the students of environmental science.

From the points enumerated above we can see great similarity between the roles and functions of the oceans and the forests. In fact they seem to be more in the case of forests than the oceans. Efficient performance of all these roles and functions by the forests would be possible only if a minimum forest area is maintained on the land surface. The question is how much or what proportion of the land area should be under perennial forest? Which part of the land should we maintain under permanent forest cover: hills or plains or both and at what proportion? We saw that slope is a major component in the Eco-system (Fig 1 in chapter 1) and it influences all other components of the earth

eco-system. What is the relation or interaction between forests and the percentages/degrees of the slopes on the surface of the land? Up to what percentage of slope should we humans interfere for their survival and development? We know that slope accelerates soil erosion and in one or two monsoon itself the top soil of a huge mountain can be eroded completely and lost to the area for ever. But if that mountain is covered with forests then the soil erosion can be reduce to minimum to nil. It is only forests that can preserve soil efficiently and effectively on the hill or mountain slopes; mechanical control is possible but it will be very expensive and often washed down by heavy rain eroding huge amount of soil with it.

Now the question arises beyond what percentage or degree of slope should we keep perennial forest cover? What are ecological imperatives with regard to use of land varying from zero to ninety degree slope? There can be few more questions of this sort. At present there are no directives on the use of slopes from the environmentalists as such, though there is a lot from the agricultural scientist's point of view which of course can be adopted and adapted to all programmes and projects of environmental sustainability and stability.

Ecologically speaking at least the same ratio between the oceans and land is to be maintained for the forest and non-forest area on the land which means 70% for forest cover leaving 30% for all other types of human activities including agriculture, animal husbandry, inland aquacultural activities, residential and urban areas, institutional areas, market areas, industrial areas, land for road, railway and airfields, security and defense related establishments, recreation and entertainment facilities etc. However some of them can be incorporated into the

hilly forest system without disturbing them and with no or least displacement of the soil depending on the feasibility, need, climate, angle of slopes in the hilly and forest areas but with no environmental pollution. The timber trees harvested should be only selectively and by cut and airlift method by helicopters. However possibilities and facilities for collection of minor forest products should be there.

Due to all the above mentioned factors we can affirmatively say that at least 66.6-70% of the land area excluding perhaps the permanently snow covered area should be under perennial forest cover and only a maximum of 30-33.3% of the land surface should be left for all types of regular human usages and activities or for his day to day interventions. Slope of the land surface is a determining factor in the land use patter on the surface of the land area. Hence we need a detailed treatment of the various factors of the slope.

Slope of the land

We must also note that slope is not an active component in the oceans whereas on the land slope is a very active and determining component directly deciding the level of existence and survival of soil, water, microbes, plants, animals and humans and to some extent indirectly affecting the quality of air, light and heat. Slopes in the oceans do not affect the level of human interventions in the sea though the depth, which is a variation of the slope, can affect many of his interventions. But on land the percentage of the slope does impose tremendous limitations on the human interventions. There are the heights as well as the latitudes as we move towards the North and South poles where the land is covered permanently with snow and glaciers that even the forests cannot survive; whereas in all the areas where humans operate, forests are a mitigating and essential

factor to maintain the ecological balance and life systems.

Slope is an important limiting factor on the human interference on the land-eco-system. Hence it is natural that we need to have a detailed study of the slopes on the surface of the land in each locality and their cumulatively limiting or beneficial impacts not only on the human life but also on other components of the earth-eco-system.

Slope is measured and expressed in three ways: 1) percentage of slope 2) ratio between rise/vertical to run/horizontal of the slopes and 3) degree of the slope. These are explained using two triangles of two different degrees of slopes and two rises/verticals as shown in Figure 1.

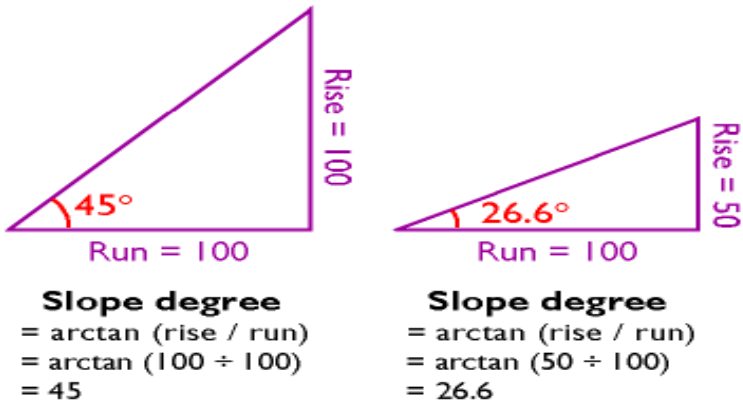


Figure 1: Two triangles of same run but different rises and degrees

NB. Arctan is a trigonometry term denoting the slope factor which can be converted into percentages also given as follows.

1) Percentage of slope is estimated by the formula: rise/run x 100 = % of slope.

In the first triangle: 100/100 x 100 =100% slope

In the second triangle: 50/100 x 100 = 50% slope

2) Ratio of the rise to the run is estimated by rise to run in feet or metre

In the first triangle: 100:100 = 1:1 (more slope)

In the second triangle 50:100 = 1:2 (less slope)

3) Degree of slope is measured by the angle between the run and the hypotenuse. The degree can be measured by using a protractor or a ready-reckoner as given in Figure 2.

In 1st triangle the angle between hypotenuse/slope and run is 45^0 (degree)

In 2nd triangle the angle between hypotenuse/slope and run is 26.6^0 (degree)

The ready-reckoner in Figure 2 also presents the above three expressions of slope in the order of percentages, ratios and degrees of slopes. Now we have instruments for measuring the slope in any of the three forms explained above. However if no instrument is available, anyone can estimate the slope at any point of any sloping land. There are three variations in this procedure.

Variation 1: Select some sample spots on a large sloping land area. Make vertical/rise cuts of one or two feet and make a corresponding horizontal/run cut at right angle (90^0) to the rise in all spots selected. One can make a wooden or metal set-square of one to two feet vertical/rise to two to three feet run to ensure the angle of the cuts be exactly 90 degree and the run of cuts are horizontally level. Measure the runs of all triangles and record them in a field book in the order of sampling. Draw scale models of all right-angle triangles in an office record book in the order of sampling with two feet vertical as common rise to all triangles of varying runs. Measure the angles between run and hypotenuse of all triangles using a protractor of student's

geometrical box and record them. From the measurements of the rises and runs we can estimate the percentage, the ratio and the degree of the slopes as explained already.

Variation 2: We can also make a fixed right angle triangle with a movable hypotenuse and markings of ratios and degrees on the vertical side to measure the ratio and degree of the slopes. Then from the vertical and horizontal measurements one can estimate the percentage of slope.

Variation 3: In this method no cuts are made; only two calibrated straight rods or sticks are needed. A measuring tape can replace the calibration on the rods. Hold one of the calibrated rods **vertically** at a point on a given slope of the land; then place the other calibrated rod **horizontally** but close to the vertical one with one end of the horizontal bar touching the upper side of the slope. Make sure that both rods are touching each other and are positioned at **right angles to each other**. **Adjust the rods and make sure the verticality and horizontality of the rods as accurately as possible by visual observation or by a spirit leveler or any locally available methods**. Measure the length of the horizontal bar from the end touching the slope to the vertically held bar to get the run of an imaginary triangle; measure also the height of vertical bar from the land to the horizontal bar to get the rise of an imaginary triangle. Plot on a paper the right angle triangle with vertical and horizontal measurements marked. From this we can estimate the following and as given in Fig 2 given below.

1. Percentage of slope is determined using the formula vertical (rise)/horizontal (run) x100,
2. The ratio between the vertical (rise) and run (horizontal),
3. Degree of slope by measuring the angle between the hypotenuse & base with protractor.

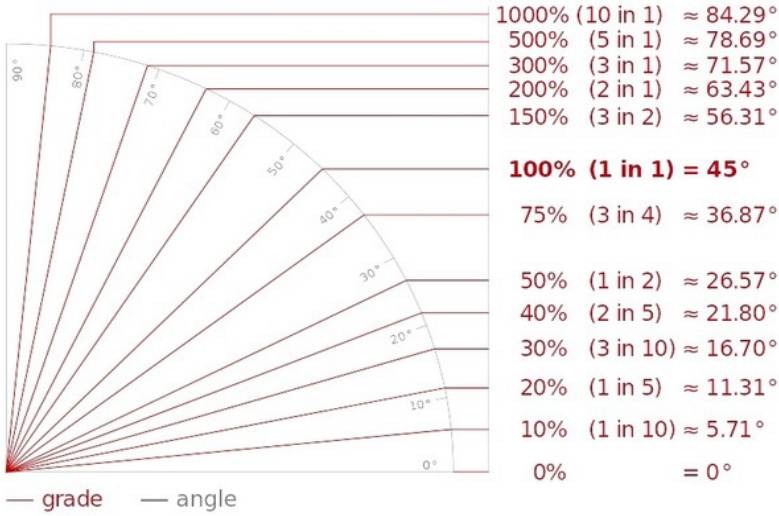


Figure 2: Ready Reckoner for Slope Determination

Table 1 is a ready reckoner giving the parallel values of degrees, gradient and percentages of slope. Figure 2 and table 1 are giving the similar values of the same slope in degrees, gradient and percent

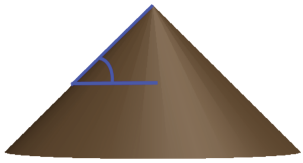
Table 1. Ready reckoner to determine the degree, ratio and percentage of slopes

DEGREES	GRADIENT	PERCENT
0.6°	1 : 95.49	1.0%
1°	1 : 57.29	1.7%
1.15°	1 : 50	2%
1.19°	1 : 48	2.08%
2.86°	1 : 20	5%
4.76°	1 : 12	8.3%

DEGREES	GRADIENT	PERCENT
7.13°	1 : 8	12.5%
10°	1 : 5.67	17.6%
14.04°	1 : 4	25%
15°	1 : 3.73	26.8%
26.57°	1 : 2	50%
30°	1 : 1.73	57.7%
45°	1 : 1	100%
56.31°	1: 0.67	150%
60°	1 : 0.6	173.2%
63.43°	1 : 0.5	200%
78.69°	1: 0.2	500%
89.43°	1 : 0.1	1000%
90°	1 : 0	infinity

Critical Angle of repose

As we all know land area used by humans consists mainly of top soil which is a mixer of sand, loam and clay. The **critical angle of repose** of most of top soil type is that angle beyond which the soil will have a propensity to slide down or collapse; we can also term it as the **angle of retention or repose**. The critical angle varies with types of soil: in clayey soil which has higher degree of adherence will have greater degree of critical angle of repose; whereas sandy soils, in which the soil particles are loosely arranged, will have a lower degree of critical angle of repose or retention. The soils in various geographical areas or locations will vary much in the texture and structure. Hence we can recommend only a range of measurements to refer to the angle of retention or the critical angle of repose.



Soil Type	Dry	Moist	Wet
Top Soil; Loose	35 - 40		45
Loam; Loose	40 - 45		20 - 25
Peat; Loose	15	45	
Clay/Silt; Solid		40 - 50	
Clay/Silt; Firm		17-19	
Clay/Silt; Loose		20 - 25	
Puddle Clay			15-19
Silt		19	
Sandy Clay		15	
Sand; Compact		35 - 40	
Sand; Loose	30 - 35		25
Sandy Gravel; Compact		40 - 45	
Sandy Gravel; Loose		35 - 45	
Sandy Gravel; Natural		25 - 30	
Gravel; Medium Coarse	25 - 30		25 - 30
Shingle; Loose		40	
Shale; Hard		19 - 22	
Broken Rock	35		45

Table 2 The Critical Angle of Repose in degree of Slopes

Flow Property	Angle of Repose (degrees)
Excellent	25–30
Good	31–35
Fair—aid not needed	36–40
Passable—may hang up	41–45
Poor—must agitate, vibrate	46–55
Very poor	56–65
Very, very poor	> 66

Table 3 Flow Property of slopes in degrees

As already mentioned in Fig 2 we can observe the angle of slopes in percentages, ratios and degrees of slope. Normally the land terrain is covered with loose top soil or loose loamy soil which has angles repose/stability varying between 35-45 degrees of slope at the normal dry condition

as given in the first two rows of Table 2. In Table 3 we find the flow property varying between fair to excellent range of "flow property" between 25 to 40 degrees. The data given in Tables 1 & 2 also helps in making a combined assessment of the range of degrees of slopes having better angle of repose for a normal top soil mixture. F**rom Figure 2, and Tables 1 & 2 we can assume the critical angle of repose ranging between 50 to 75 per cent or 1:1.3 to 1:2 ratio or 26 to 36 degree.** This is a simple practical method of estimations of the critical angle of repose at the field level and it can be understood by ordinary people with some practice. However readers must keep in mind that **soil is such an unpredictable substance like the weather:** yet now-a-days weather predictions are satisfactorily accurate. So too the angle of retention/critical angle of repose for most of the soil conditions on the surface of the earth ranges around 26 to 36 degree angle or 50 to 75 per cent or 1:1.3 to 1:2 ratio.

Soil Types

Use of Table 1 requires some amount of knowledge about the soil types or class and how to determine more or less the type of soils we are dealing with in determining the critical angle of a slope. Soil consists of three types of particle: clay, silt and sand; but a mixture of these three components provide a number of combinations in the actual field conditions like all the names given in Fig 3, such as clay, clay loam, loam, sandy clay, sandy clay loam, sandy loam, loamy sand, sand, silty clay, silty clay loam, silty loam and silt. With a little practice any one can determine more or less the type of soil on his farm land as a whole or in different parts of the farm if there are variations in the soil. But as the rainfall pattern changes the moisture content of the soil also changes resulting in the change of angle retention too: for sand it is the least and for the clay

it will be maximum without applying any pressure. But for normally cultivated top soil with more or less equal amount of sand, silt and clay will have on an average stability of angle of retention ranging between 30 to 40 degree slope. Hence we must give sufficient margin of error in estimating the critical angle of retention.

Field level determination of soil types

Now at the field level there is a simple method of determining the type of soil one is dealing with. Take a colorless, transparent (glass or firm transparent plastic) cylinder of at least one to two feet high and a few (3-4) inches of uniform diameter. Fill it with some soil of which you want to determine its class, up to half the height without any stones; fill the rest with water and stir the mixture of the soil and water thoroughly a number of times till the soil becomes fully mixed with water to become a muddy water in which the small soil particles can freely float; keep it for some time and allow the soil particles to settle down; again stir the content thoroughly and leave the content to settle down; repeat the same a few times. Now bigger and heavier particles like sand will settle down to the bottom followed by smaller particles like silt and finally the clay particles, often forming clear and distinct layers of them; most of the times, you will be able to distinguish visually the layers of sand, silt and clay from the bottom to top; measure the heights of these three layers and estimate the percentages of heights of sand, silt and clay in the soil column. Using the soil pyramid triangle (Fig 3) as a ready reckoner any one can identify the type of soil you sampled. For greater accuracy you can have a number of replications and take the average of them to estimate the percentage of sand, silt and clay in the sampled soil. The sum of the percentages of sand, silt and clay will be hundred. Compare the percentage

of sand, silt and clay with Fig 3; observe the area where the percentages of sand, silt and clay meet inside the triangle to estimate the general type of the sampled soil. All the land users of any form should have a practical knowledge of the type of soil they are having and the critical angle of repose of their land slope or they should have similar communication from the soil conservation department of the country or state or district.

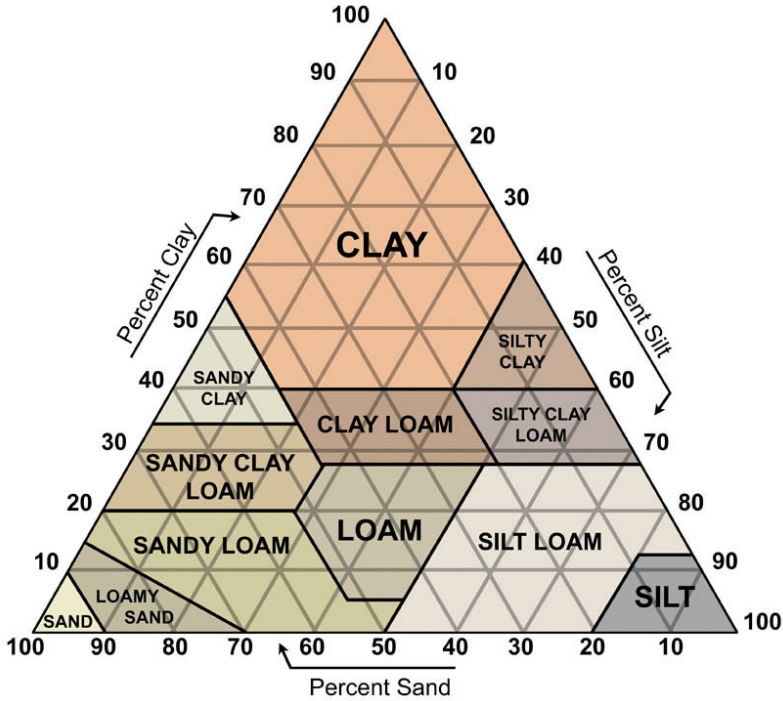


Fig 3 Soil pyramid triangle

NB. Milton Whitney (1911) published the first plot of soil class boundaries in Cartesian coordinates (which became a right angle triangle, because all fractions must add to 100 per cent).

Terracing of land

Strictly and economically speaking terracing can be and should be done maximum only up to a slope of 20 percent or 1:5 ratio or 11.31 degree. All the lands between 20 to 33.3% slope should be placed under tree crops of orchards or small timber trees in contour lines. For terracing an area applications of the above method of estimations of the degree of slopes will be useful. At the field level an individual can make an adjustable or fixed set-square of wood or metal with a fixed rise and variable run-ratios of 1:1 to 1:2. Estimate the soil type of a given area and estimate the ratio of rise to run and the maximum angle of retention it can have. All the land above the angle of retention should be placed under perennial forest cover. Terraces can be made only on lands with slopes lower than the angle of retention. The rises of terraces may vary between one to four feet in height and the runs will be of corresponding widths. Rises above 4 feet is not advisable since there will be more chance of the collapse of the rise itself. To prevent the collapse of the rise, give a slant to the rise itself. With some experience any one can perfect his ability to assess the slant to be given to the rise depending on the soil types: more clayey the soil higher could be the rise and lesser will be the angle of slant and more sandy the soil lesser should be the rise but greater will be the angle of slant.

These types of thumb rules can be useful for anyone to decide the patterns of land use, like area under seasonal crops, annual crops and perennial crops or short term crops, medium term medium sized crops or tall growing long term crops. It also helps to decide which areas are to be leveled, plotted of what size and length, which areas can be irrigated and which cannot be irrigated. As already said the land use pattern is decided by the angle or degree of the slope of the land.

Ecologically two points should be very clear: 1) every country should have a detailed survey of the topography of its land surface clearly marking areas above the critical angle of repose that should be under perennial forests. 2) the ratio of total forests to non-forest area (possibly excluding the permanently snow covered areas) should be maintained 70:30 ratio even if there is no area above the critical angle of repose.

UN and FAO are still to understand the cruciality of determining the land use pattern based on the critical angle of repose and to recommend the same to all member countries to fix the critical angle of repose in different parts of each country depending on the type of soil and the intensity of rainfall to decide upon the percentage of area under perennial forests. **In general all the slopes above 1:3 ratio, excluding the permanently snow covered area, should be under perennial forest cover and should never be subjected to cultivation.** The critical angle of repose is the most crucial determining factor to decide the land use pattern: which area to be placed under the perennial forest cover, which area to be under cultivated trees/orchards and which areas is to be placed under seasonal cultivation for various human usages.

World forest scenario

At present according to FAO/UN the world average cover of forest is 31 per cent which is much below the ecological requirement mentioned above. Unfortunately even the FAO/UN body recommends only 33.3% of the land area of each country to be under perennial forest cover. There are many countries in the world which do not have even 30% of the land area under forest. Globally 108 out of 192 listed countries have forest only less than 33.3% and about 38 countries have forest between 33.3% and 50%

and about 32 countries have forest between 50% and 70 % and only 14 small countries have forests above 70 per cent.

Slope which is a key factor in determining the ecological stability does not figure at all in the FAO/UN declarations or recommendations: global gross ignorance! At the global level FAO/UN should promote topographical survey to find out the areas above and below the critical angle of repose and forcefully recommend to all the countries not to tamper with areas above the critical angle of repose and to leave all the areas above the critical angle of repose under perennial forests. Under normal range the critical angle of repose is 30-40 per cent slope. But for all practical purposes with sufficient margin of safety it is better to fix the critical angle of repose at 33.3 per cent or a slope of 1:3 ratio of rise to run. With the present methods of satellite imaging techniques we can accurately and clearly demarcate easily the areas above the critical angle of repose at 33.3 per cent which should be maintained under perennial forest cover by every country. Here we can have two types of perennial plantations: areas between 33.3 to 45 per cent slope could be placed under planted timber trees and the areas above 45 per cent slope is left for ever under natural forest cover. The areas between 20 to 33.3 per cent should be placed under perennial orchards planted on contour lines while areas between 10 to 20 per cent also can be planted with short and medium size types of fruit trees like guava, lime, lemon, orange, pomegranate etc., or terraced for seasonal cultivation. The lands of slope between 5 to 10 per cent are broad bench or wider terraces for seasonal cultivations and lands of slope between 0 to 5 percent can be cultivated without much terracing or structuring. These recommendations are tentative and indicative. UN/FAO should work on suitable recommendations and promulgate them to all member countries for promoting sustainable and eco-friendly land use.

Indian scenario

According to 1952 and 1988 Forest Policy of India, we are supposed to maintain 66.6% of the hilly areas and 33.3% of the plain areas under perennial forest cover. But at present according to Shri Prakash Javadekar the central Environment Minister's report (2020) the total forest and tree cover of the country is 80.73 million hectares which is 24.56 percent of the total geographical area of our country without mentioning the distinction between the plain and hilly areas. Whereas for the ecological balance of our country there should be at least 70% of the reported land area should be under perennial forest cover. However it should be clear that all the areas above 33.3% slope should be under perennial forest cover even if the forest area becomes above 70 per cent of the total area. Accordingly we can decide how much of the plains be under perennial forest excluding orchards. The recommendation of minimum forest cover at 66.6% in the hills will be ecologically untenable, if the hilly areas are above 33.3% slope, is more than 66.6 per cent. Ecologically all the areas above 33.3% slope should be under perennial tree cover. The recommendation of forest cover in the plains should be based on the locational specificities like stream and river banks, surroundings of inland lakes and reservoirs, uncultivable areas in the cropping lands, road side plantations, farm and agro forestry, parks and recreation areas, botanical gardens, wind breaks and shelter belts, etc. and not only based on the percentage recommendation. Rubber plantations cannot be considered forest area since periodic replantations are to be done. Trees in the tea gardens cannot be considered as part of the forest cover; however adequate tree cover in the cardamom plantations can be considered as forest.

The slope which is a key factor in determining the ecological stability and areas of compulsory forest cover

does not figure at all in any of the Indian environmental declarations and documents which again is a very serious lacuna. Indian government should initiate topographical survey to determine which land areas are above and below the critical angle of repose which can be fixed at 33.3% slope. In India a lot of hilly areas which should have been under perennial forest, are being placed under shifting and regular cultivation causing huge amount of soil erosion amounting to about 6000 million tons per year which again reduce the soil fertility and increase depletion of water sources and drying up of many rivers. The ill effects of soil erosion are unimaginable and long lasting. Imagine a country with only barren land areas without water; no plants, animals; no human being can survive on such a land.

The total reported geographical area of our country is estimated to be 305.85 million hectares, though the estimated total area is supposed to be 328.7 (329) million hectares. Let us base our study on the reported geographical area. Then we need to set apart a minimum of 214 million hectares under forest if we accept 70% of the area under forest for the ecological stability of our country. Then the maximum area of 30% should only be left for agriculture (including animal husbandry) and for other human usage; that will be only 91.85 million hectares. At present the net sown area in our country is 140.5 million hectares or 46 per cent of the total reported area which is beyond the ecologically permitted land area for agriculture. That means we are over-cultivating 48.65 million hectares. We also have 302.3 million cattle and buffaloes with low productivity to support besides 233.5 million other types of domestic animals excluding 851.8 million poultry birds. Thus both agriculture and animal husbandry sectors heavily weighs down on the eco-system of our country. Above all a population of 1300 million is an extremely heavy load on

the eco-system of our country: the optimum population may be less than half or one-third of the present.

The 70 per cent or 214 million hectares of supposed to be the forest area of India will include the major mountain ranges like Himalayan Mountains, Karakoram and Pir Panjal Range, Eastern Mountain Range or Purvanchal Range, Satpura and Vindhaya Range, Aravalli Range, Western Ghats and Eastern Ghats besides scattered hills in the Deccan and Chottanagpur plateau. Besides these ranges and hills it also will include and land at and above 33.3% slope. The area covered by Himalayan range is estimated to be 59.5 million hectares. The Deccan plateau which is about 88.8 million hectares, of which about 30.4% or 27 million hectares is also included into the net sown area. Hence the uncultivable hilly areas of Deccan amounting to 61.8 million hectares are already part of the total forest system. But if the areas at and above 33.3% in India are more than 70 per cent, then all those areas should be under perennial forest cover to maintain the ecological stability of our country. That is possible only after making a topographical survey of our country by remote sensing or some other techniques to determine exactly how much area of our country is at and above 33.3% slope. Such a survey is one of the first steps to be taken by the Environmental Ministry of our country.

For a proper forest and agro-ecological assessment and planning we also need to know the existing land use pattern of our country and also the area under degree or percentage of slope (the critical angle of repose) above which land should be under permanent forest cover. Though there are differences in the various sources of available statistical data with regard to land use pattern in our country, we shall base our analysis on the data in table 4 as given below though it is **incomplete without the data on percentage or ratio or degree of slope:** Environmentalists all over the

world still has to realize the importance of including the topographical survey of the degree/percentage or ratio of slopes in deciding the land use pattern.

Table 4: Land Use Pattern in India

(Trends in Land Use Pattern in India: 2011-12 by IIM Ahmadabad)

No.	Geographical Regions	Area m.ha (%)
1	India Total estimated area	329.0 0 (?)
2	**Reported area**	**305.85 (100)**
3	**Forests 2015**	**70.01 (22.9)**
4	Not Available for Cultivation?	43.48 (14.2)
5	Area under non-agricultural uses	26.28 (8.6)
6	Barren and un-cultivable land	17.19 (5.6)
7	Other uncultivated land excluding fallow land	26.25 (8.6)
8.	Permanent pastures & other grazing lands	10.31 (3.4)
9	Land under Miscellaneous tree crops & groves	3.19 (1.0)
10	Cultivable waste land	12.74 (4.2)
11	Fallow Lands	25.61 (8.4)
12	Fallow other than current fallows	10.61 (3.5)
13	Current fallows	15.00 (4.9)
14	**Net Sown Area at present**	**140.51 (45.9)**
15	**Total Cropped Area**	**193.85 (63.4)**
16	**Area Sown more than Once**	**53.34 (17.4)**
17	Arable Land	182.06 (59.5)
18	**Cultivated Land: maybe including the plantations crops**	**155.51 (50.8)**
19	Net Irrigated Area (Net Irrigated Area over Net Sown Area)	63.56 (45.3)
20	Gross Irrigated Area (Gross Irrigated Area over Gross Cropped Area)	88.41 (45.6)
21	Cropping intensity (gross cropped area/net sown area)	(138%)

NB. In Table 4, no data is available on the land above or below the critical angle of repose.

F. Area under agriculture/animal husbandry

Any land used for agriculture or animal husbandry should have a conducive climate for at least one growing season; secondly it should be below the critical angle of repose. Depending on these two factors every country should freeze the land area under agriculture and animal husbandry. If country is not having any land below the critical angle 33.3% and not having adequate duration of at least one cropping season 3-4 months then it should not go for any activities of agriculture or animal husbandry. People may grow plants in containers or in glass houses and rear small animals in cages but not on land on a commercial scale. If the country is too small like Singapore, Monaco and Vatican City-State, it is highly advisable to refrain from any agricultural activities. Countries like Greenland, Finland, Iceland and other countries falling with the Arctic Circle have very low percentage of land under agriculture, mainly due to very low temperature throughout the year; their economy banks mainly on fishing. The percentage of land available for agriculture in Egypt is around 3.8 per cent due to its desertic nature of the land. There are about 25 countries in the world which has less than 10 per cent of the total area under agriculture.

II. Ecological Constraints

There are several constraints in our eco-system; we shall deal with them one by one.

1. Soil erosion and top soil loss

Fig 4 Soil Erosion

The saying "One foot soil decides the destiny of mankind", is so true in the sense that about 95% of the world's food requirement is produced from the top one foot soil: all the cereals, millets, pulses, oil seed crops, vegetables and medicinal plants need only top one foot soil to grow. Even the tree crops derive their nutrients from the top soil; the deeper roots are for anchoring and drawing water from the deep soil. Nearly half of the most productive soil has disappeared from the world during the last 150 years.

In the US alone, soil on cropland is eroding 10 times faster than it can be replenished. If we continue to degrade the soil at the rate we are now, according to FAO/UN the **world** could run out of **topsoil** in about 60 years. The loss of top soil in India is estimated to 16.35 tons per hectare which means 5334 million tons per year from the land area,

whereas in US the per hectare per year top soil loss is 10 tons per hectare, in Europe it is about 2.5 tons per hectare per year and in China it ranges from 7.65 to 49.38 tons per hectare per year. The modern combination of intensive tilling, lack of cover crops, synthetic fertilizers and pesticide use, has left farmland stripped of the humus, nutrients, minerals and microbes that support healthy plant life.

Hence maximum attentions should be given to control the soil erosion and water conservation: both go together. For this all the area above 33.3% slope should be under perennial forest cover along with various soil and water conservation structures built into wherever they are needed; structures should be installed to control stream bank erosion; check dams, anicuts and barrages should be constructed; in short water in the forest areas should be made to "walk and not run"; agricultural land should be bunded and terraced with proper irrigation and drainage structures and tanks for collection of excess rain water or run off.

In India the catchment areas of Chambal river is a clear example of gross soil erosion which has not only destroyed one of the best fertile delta land tract but also lead to the change of life style of the people into highly anti-social behavior into notorious criminals and dacoits. Thousands of hectares of most fertile land is still lying as heavily eroded waste land.

NB. Students of environment science should make a special study of soil and water conservation structures to become more effective environmentalists.

2. Loss of organic matter

"Organic matter is the soul of the soil" is another saying. Normal top soil on an average contains by volume

45% minerals 25% soil air, 25% soil water and 5% organic matter. The organic matter, though least in amount and is present everywhere in the soil volume plays the key role in maintaining the soil fertility and with the erosion of top soil the soul of the soil goes away without anybody being aware of it.

Organic matter in the soil, consisting of living and dead materials of decomposing or decomposed plant or animal tissue, serves as a reservoir of nutrients that microbes can feast upon while they provide nitrogen and other plant nutrients to growing plants and trees into which carbon is stored up in the form of carbohydrates in food materials, woody material etc. which when digested and burned releases the heat which we use for cooking etc. When such large woody areas are buried very deep in the underground for millions of years, they become the coal. More the organic matter in the top soil, greater will be the number of organisms in the top soil, greater will be the soil fertility and better will be the plant and crop growth on the top soil.

3. Deforestation

It is estimated that between the years 2011-2015, about 20 million of hectares of forest was cut down in the world. Now the rate has gone up to an average of 28 million hectares per year. That amounts to loss one football field (averaging 0.72 ha) of forest per second and 86,400 hectares per day or 22.7 million hectares per year. We have already seen that for an ecological sustainability, any country or the total land area of the earth, there should be at least 70% of its area under perennial forest cover. Less than adequate forest cover and increasing population leads to climate change affecting food security. In a myriad of ways climate change induces malnutrition, poverty, degradation of soil and desertification.

Climate change reduces agricultural yields and increases the prevalence and spread of nutritional diseases. Projections show that climate change will increase stunting by 30 percent to 50 percent by 2050. The effects of climate change are closely linked with malnutrition in poor communities. Currently, 49% of India's land is under the onslaught of drought and slow desertification. During a drought, millions more are at risk for falling into poverty and food insecurity. Multiple years with droughts creates chronic poverty to hundreds of millions. High consumption and a growing population are inextricably linked to global warming and climate change and India is expected to be one of the countries, significantly to be affected by climate change. One of the biggest issues confronting Indian agriculture is low productivity. India's food production is highly vulnerable to monsoon variation. About 65 percent of India's cropped area is rain-fed. Because large parts of the country already suffer from water scarcity and depend on groundwater for irrigation, further droughts and changing monsoon seasons impact the production systems on which millions of people depend on for their basic needs.

4. Indiscriminate grazing

In many countries especially in India, the animals are allowed to graze freely on the terrain causing tremendous soil erosion. Animals should be kept under stall feeding not only to prevent soil erosion but also to collect their dung and urine which have very high manure value. Free grazing incur reduction in the productivity of animal both milk and meat as they spend extra energy to go up and down on the slopes in the sun and rain. No free grazing should be allowed not only to protect the environment but also to protect from the degeneration of the animal population by their indiscriminate inbreeding.

5. Canal/stream/river bank erosion

Soil gets eroded on both sides of the streams, canals and rivers, the consequences of which are easily understandable to anyone. The banks should be fortified with stone or concrete structures besides a vegetative/forest cover of suitable width on both sides of the streams and rivers. Normally the width of such vegetative belt should be between 10 to 100 meters depending on the width of the stream or river. In fact all flowing water bodies should have mechanical plus vegetative structure on either sides or all around as a protective layer to prevent soil erosion. Systematic planting of trees like banyan tree, weeping willow, palm trees, bamboo, and similar trees of good root spread can be planted all along the banks of rivers. In every place there will be some naturally growing trees and bushes along the river banks; they are the best for that area for planting to control stream bank erosion. Trees belonging to banyan tree species have the advantage of sending many roots into the soils and reinforce the river banks. Most of the banyan tree species have extensive root system and are very tolerant to hard pruning of branches and leaves which are very useful to feed the goats and cattle.

6. Preservation of islands

Any island in any water body like rivers or lakes should be preserved intact either by built-in structures of stone or concrete or vegetative methods. Where there is strong force of water flow stone or concrete structures are needed while where the water is remaining still or stagnant vegetative structures (closely planted mangrove plants or cutting of certain species of banyan trees) are enough. The whole purpose of the exercise is to stabilize the islands for some human or animal use. In the rivers like Ganges and Brahmaputra many islands appear and disappear every year

which phenomenon is totally opposed to the idea of a stable river island eco-system. Such islands should be preserved by all means for various purposes including tourism.

7. Inland water bodies

Within a country or state there will always be some natural water bodies like lakes, ponds, canals, marshy areas etc. are there. All of them should be preserved fully if not developed further with fortifications all around both vegetative and man-built structures. No one should use it for any other purposes other than recreation, fisheries and aquaculture; if the area is big and long like a river or lakes it may be used for transport. All water bodies should be preserved as far as possible in its natural form of depth and area. The areas around Chilika Lake in Orissa, though a very rare type in the world and its flora and fauna resources are unique, are being subjected to encroachment by people and its eco-system is being destroyed. Similar things are happening in and around Bangalore where there were many natural water bodies. A senior engineer in the department of the minor irrigation reported that, in addition to 12 lakes in Bangalore north thaluk, the people have plans to fill nine others in Devanahalli thaluk and 44 lakes in Chikkaballapura district. Similar things are happening in all the states in India. In fact no water body is a constraint in land use but remains an immensely valuable asset. No lake should be filled under any pretext. Further planned reclamation from the sea is advisable like they do in Netherlands. The Kuttanad in Kerala the only place below the sea level in India should never be leveled as many people are doing it for making house plots or for agriculture. Even the traditional form of paddy cultivation is not viable or advisable in such place. The whole area should be planned for preservation in its natural status along with possibilities

tourism, fisheries and aquaculture. All road and transport structures should be on pillars and land filling with soil from outside should be done. Such constructive planning is necessary for inland water systems. "**Never fill any inland water bodies" is the nature's injunction.**

8. Preservation of hills and rocks

Like the water bodies hills and rocky areas should also be preserved. If at all any removal of soil or rocks are needed it should be done in such a way that least of soil erosion should happen. Normally all the hills and slopping areas at and above 33.3 per cent should be placed under perennial forest cover. As far as possible the natural topography of the land should be maintained as it was.

9. Transport system in the hills

If any transport system of roads or railways is to be built in the hilly areas and across the hills and mountains tunneling would be best for ecological preservation. Structures should be built in such a way that no soil erosion should take place. Construction of Konkan railway and Delhi metro system are examples of handling the removed soil and other debris ecologically.

10. Mechanization of farm

As the years go by, mechanization of farming has become a necessity even in India though its capital and running costs are going to be high in terms of money. Pre-mechanization times were marked by high human cost which was not at all considered a cost in farming: it was never accounted. For mechanized farming the farm size becomes a crucial factor: bigger the farming plots better for effective mechanization. Bigger and multi-operational farm machines need bigger farm plots. Bigger the farm

plots or farm areas imply least slope of farming land. That means we cannot go for broad terracing of a land which is more than 2.5 per cent slope. Even for perennial crops we cannot go for terracing in an area which is more than 10 per cent though people make terraces even on steep land slopes to get a few feet wide terraces. Thus farm size becomes a critical factor in executing mechanical operations. A minimum 25 acres (10 ha) is needed for maintaining average mechanization in a farm. In India more than 80% of farms are small and marginal having less than 2.00 hectares, another 12% are semi-medium farmers having 2-4 hectares; thus 92% of the farm lands below semi-medium land holdings which in the coming years will be divided and subdivided year after year leading the whole agriculture sector in India into an irredeemable economic and structural condition. **Only farms of acreage more than 10 to 20 hectares will be able to survive in the farm sector. In India due to law of inheritance, endless division and subdivision landholdings is taking place leading to great ecological and economic problems; as early as possible a revolutionary change is needed.**

It is high time that we abolish the individual absolute ownership of the land and nationalize all the farm lands and structure them into economically viable units according to the agro-climatic conditions of the regions. All lands should belong to the government and all those who want to cultivate should apply formally and permission is granted for a number of years and the same is continued based on their performance. In Holland when hundreds of acres were redeemed from the sea and made it into plots of 25 acres each for growing fruit trees, government called for couples interested in farming, whom they interviewed both husband and wife together to check on their aptitude to farm life and if satisfied only they are allotted the plot.

Their job is only to produce; all the inputs and outputs management will be done by the government. Similar such systems are necessary in India too. Today marginal, small and semi-medium farmers constitute 92% of the farmers in India; after ten years the percentage of the same categories will increase to 95 or 98 per cent. What will any farmer do with such small holdings? **Above all such farming systems will be doing irrecoverable harm to the eco-system of our country.** At the world level only 11% of the land is under cultivation; only India, China, USA, France and few other countries have extensive agricultural lands. **Hence restructuring of agricultural system is very necessary not only from the stability of agricultural economy point of view but also from the sustainability of the ecological system of the country point of view. People seldom are aware that maximum harm is done, to the eco-system in all the countries especially in the tropical agricultural areas, is due to the type of farming done by people.**

11. Area under animal husbandry

At the global level 77% of the agricultural land used is for animal husbandry according to Fig 5 given as follows (same as in Chapter 2 Fig 5). While 82 per cent of calorie supply and 63% of the protein supply are from crop husbandry while animal husbandry provides only 18% of the calories and 37% of the protein. Hence the allotment of 77% of land area to animal husbandry is ecologically untenable and socially unjustified. Socially unjustified because not only 77% of the land area is used for animal husbandry which provides high cost sophisticated non-vegetarian food items for small minority of the world population: which is ecologically unsustainable, economically unviable, socially unjustified. It is simply the diversion of the large quantities of natural resources for the benefit of a small minority

depriving the basic needs to a large majority: ecologically such production systems are untenable.

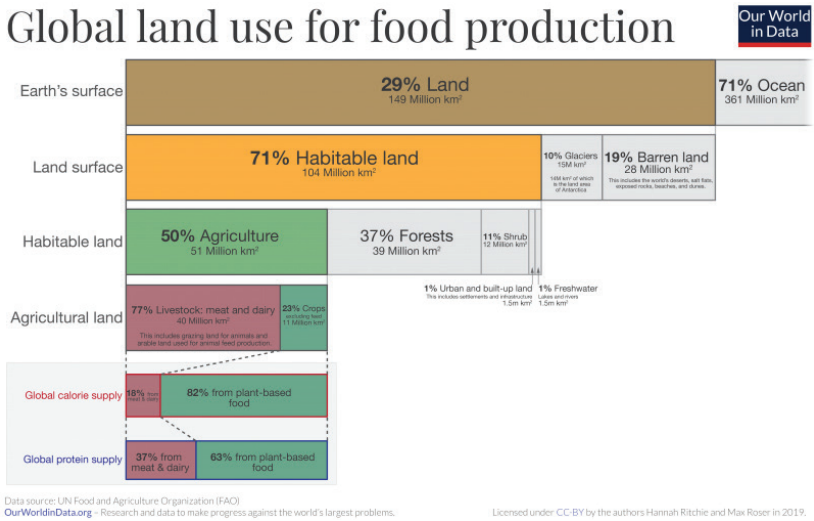


Fig 5. Global land use pattern.

Such unequal allotment of land resources to animal farming is ecologically detrimental not only globally but also to any individual country. After all, all farm animals are vegetarians; why should humans be **too much of nonvegetarians becoming victims of stomac cancers**?

12. Nutritional deficiencies

All over the world there is a growing tendency of consuming too much of non-vegetarian food items with too much liquor and/or highly sweetened soft drinks. Such tendencies are creating tremendous deficiencies in the vitamins and minerals combined with over consumption of carbohydrates including fat and proteins creating obeisity and other imbalanced and over nutritional health problems. At present people all over the world are going too much by taste forgetting that food is basically for balanced supply

of carbohydrate, protein, fat, 14 vitamins and about 30 minerals. Among them vitamins and minerals are protective nutrients securing hormonal and enzymatic balance which ensures proper fuctionaing of all physiological and mental activities of growth and development along with natural resistance to diseases; hence they are known as protective nutrients. Humans are becoming more and more deficiant in several of the 30 minerals and 14 vitamins for which crop plants are the best source. There are more than 40 types each of 1) leafy vegetables, 2) root vegetables, 3) immature pod vegetables, 4) fruits and 5) spices-condiments; why nature created all of them? These 160 types of vegetables and fruits are created by Nature for providing about 30 minerals and 14 vitamins; condiments and spices are created for providing a number of essential oils with various medicinal properties. The recommendations of ICMR nutrition committee headed by late Dr. C. Gopalan as early as early as 1980's to include all the three types of vegetables amounting to half of one's daily food intake along with a cup of few cheap fruits chopped and mixed to ensure supply all vitamins and minerals, is no more remembered and promoted by any one in the health and medical department. Today we humans are forgeting and forgoing these varieties of vegetables and go for processed food items and airated and highly sweetened soft drinks inviting all types of sickness and diseases. Incidences of nutritional dificiency diseases are increasing exponentially in the world and **super speciality hospitals** are mushrooming everywhere and a new medical business enterprises are also becoming popular under the garb or **medical tourism** and people are falling easy prey to both these enterprises. Nutritional deficiency is linked with over-population and rampant disease incidences both mentally and physically. (more about it in chapter 09 on Management of the Most Intimate Human Environment).

13. Over-population

At the world level India poses as a thriving economy; but it is struggling with poverty and hunger. In the Global Hunger Index, India ranks 102nd out of the 117 countries studied. Forty-six million children in India remain stunted and 25.5 million more are defined as "wasted" meaning they do not weigh enough for their height and age. India's child wasting rate is extremely high at 20.8%, the highest wasting rate in the world. It is usually the result of acute and significant food and nutrient shortage and/or various diseases. With 54% of the children under-five years of age are stunted, wasted or overweight, India fares the worst among the South Asia countries in child health. A lot of food is wasted in India: the waste of food grains due to poor supply chain management in India alone amounts to total consumption of United Kingdom. Research suggests that $1 spent on nutritional interventions in India could generate $34.1 to $38.6 in public economic returns amounting to three times more than the global average.

Though we produce nearly 300 million tons of cereals and millets after deducting the estimated loss of 30 percent of food grains between the threshing floor to the mouth of the consumer what is left for the consumption of humans and domestic animals is totally insufficient. About 29.43 million tons go for cattle feed, population of poultry stood at over 851.8 million in 2019 across India and they need about 35 million tons per year. The pig population in India is about 9.06 million; their average requirement at the rate of half kg grain per day may require about 10 million tons of grain. Simple estimations like these will leave only around 135 million tons for 1300 million people in India. That corroborates the findings on the Indian poverty and incidence of starvation causing wasting disease among

54% of the children and 51% incidence of anemia in the whole of India population. It is estimated about 75% of the pregnant women are anaemic in India and put on an average weight of 5kg during pregnancy compared to the world average of 10 kg. Malnourished women in reproductive age cannot deliver healthy babies, thereby perpetuating the intergenerational cycle of under-nutrition and nutritional deficiency diseases. It is estimated that 69 percent of deaths of children below the age of five in India are related to nutritional deficiency diseases. These disasters are yet to be recognized as environmental by world and India environmental bodies.

Whenever the Indian government makes tall claims of self-sufficiency in food production they sweep these hard facts under the carpet. India's biggest environmental challenge still remains food and nutritional security to its masses. India experiences food shortage which results in chronic and widespread hunger amongst a significant number of people. Big initiatives have to be taken to improve food security as India faces supply constraints, water scarcity, small landholdings, low per capita GDP and inadequate irrigation with burgeoning population. Most of the farm workers in India are still continuing their age old farming practices of low efficiency and productivity. There is a need to train them into new skills and technologies required for productivity growth. The Indian population is exploding and we are ignoring the resultant problems in the future. It is expected that by 2024-25 India will outrank China which is number one in population. Frankly speaking India can support not more than one-third of its present population. Both politicians and people need to realize this hard fact and take adequate steps to curb this colossal problem. **Poverty is one of greatest environmental disaster to any country.**

All these will have tremendous impact on Indian environment. A study of UK based Input Output Processor (IOP) published *Environmental Research Letters,* equates the impact of having one fewer child to reducing 58 metric tons of CO2 for each year of the parent's life. There are other ways to reduce one's carbon footprint; going car-free saves emissions by 2.4 metric tons and eating a plant-based diet 0.82 metric tons and so on.

Even if we ignore the numbers, the environmental ill-effects are being felt by all of us. Cities like Delhi and Bengaluru will run out of water in few years so too most of the cities in India. According to the Centre for Science and Environment, every third child in Delhi has irreversible lung damage caused by air pollution. Educational institutions are struggling to cope with the demand of an ever-increasing number of students. Recently Kerala faced the problem of seat shortage at the plus one level admission. Forests are shrinking to make way for increased timber marketing.

Karen D'Souza, an editor and writer, speaks passionately about her decision to not have children. "The planet is in crisis, be it climate change, crime and violence, pollution levels," she said. "I think I would be totally irresponsible to bring a child into this world. Not only would he/she have a questionable future, but they'd put more pressure on a planet that's gasping for breath." Following are ten facts about India collected from various sources.

Facts of Indian population: negative and positive

1. According to U.N. estimates, India's current population of 1.32 billion is projected to reach 1.8 billion by 2050.
2. Indians account for nearly one-sixth of the global population and one in three people living in global poverty, according to statistics from Yale University.

3. The fertility rate of Indian women has more than halved over the last 40 years, down to 2.2 births per woman. Falling fertility rates are important in that they typically correspond with rising life expectancy and quality of life.
4. Around 31 percent of Indians currently live in urban areas, but that number is projected to climb to near 50 percent (830 million people) by 2050.
5. Currently, India is home to five megacities; this number is slated to increase to seven by 2030. A megacity is a city of more than 10 million people.
6. Delhi is projected to remain the second most populous city in the world in 2030, adding 9.6 million inhabitants in that time.
7. While only 3,00,000 men agreed to vasectomies in 2008-09, and about 5.5 million women agreed to use an intrauterine contraceptive device (IUCDs) to avoid pregnancy. These procedures are sponsored by the government to promote population control is met with poor response; now-a-days nothing is heard about population control at all.
8. The number of married women who regularly using contraceptives has gone up from 13 percent in 1970 to 48 percent in 2009 is positive.
9. Indians have added almost a decade to their life expectancy in the past 25 years, with average life expectancy up to 69 years.
10. India registered 90,000 fewer infant deaths in 2016 as compared to 2015.

Though there are several positives, the scenario of our country is still grim. From the environmental points of view India should have only one-third its present population.

Following are the major impacts of over population in India.

01. More mouths to feed, problems of nutritional deficiencies,
02. Vast majority are living in lower standard,
03. Increased incidence of poverty,
04. Overcrowded cities, shortage of facilities
05. Increased incidence of spread of many diseases.
06. Insufficient natural resources to provide adequate goods and services.
07. Inadequate facilities, such as housing, water supply, medical, education, etc.
08. Problem of starvation and malnourished population, poor work efficiency,
09. Education facilities may not meet the requirements of the entire population,
10. Rampant unemployment and under employment,
11. Higher crime rate due to unequal distribution of wealth and facilities,
12. Environmental pollution, deforestation for more farming, housing etc.,
13. Insufficient agricultural production is to meet the requirements of all people,
14. Lower availability of food, Increasing food price, increased hording,
15. Less resources are available to research and development,
16. Lower life expectancy and life of misery to vast majority of people,

17. Increased unemployment in rural areas forcing them to migrate to cities,
18. Large number of people lives in unhygienic conditions,
19. Birth rate is relatively still high,
20. Over-crowded hospitals leading to low availability of proper medical facilities,
21. Rampant forced child labour rather than sending them to school,
22. Economic depression and slow business development and expansion activities,
23. **Population pressure on infrastructure:** poor development of infrastructural facilities,
24. Increase in the number of slums, overcrowded houses, traffic congestion etc.,
25. Over-exploitation of natural resources, also scarcity of resources,
26. **Decreased production and increased production costs,**
27. Distribution cannot catch up with the increasing population,
28. Inflation is the major consequence of over population,
29. Inequitable income distribution among people,
30. Inequitable service distribution and unemployment,
31. Scarcity of resources: land, water, forest, housing, education medical, services etc.
32. Over population is an environmental disaster for any country

Total population within the manageable range is one of the ecological constants. At any given time the total

population of a country or the world should be within the limit of the ecological productivity in terms of food items and all the consumer products. Figure 6 gives an idea of the relation between population growth curve and the production curves of various natural resources in general, per capita availability of food, population growth, industrial output per head and what would be the pollution rate as the years go by from 1900 to 2100. The curves are indicating that natural resources in general, per capita availability of food and industrial output per head are on the decline while the population and pollution are on the increase. There are already signs of increasing world famine and famine related diseases. Most of the diseases in the world and in India are happening due to imbalanced and poor nutrition. The modern food industry caters mostly to taste and not balanced nutrition. People are carried away by the false advertisements on food preparation and intake. There are enough convincing studies showing how the present food technology is promoting unhealthy eating habits and thereby increasing incidents of under and mal-nutritional disorders. The natural resources are decreasing faster even though population and pollution may decrease; both per capita food availability and industrial output are on the decrease. According to the growth model by 2050 the ecological and economic situation will be grim…..wait and watch…..how the present growth model will behave in the future.

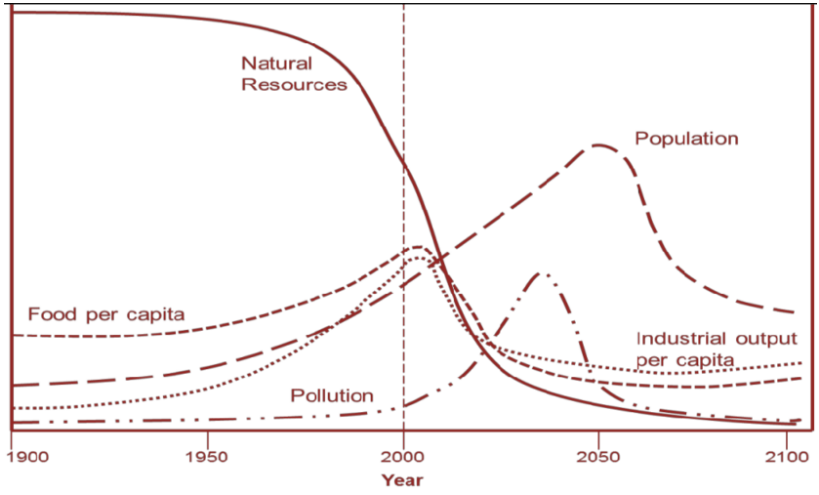


Fig 6: Limits to Growth Model

Concluding Remarks

An attempt is made in this chapter enumerate and describe briefly the Constants and Constraints of world and Indian eco-system. There may be some more of them and the readers and students of this chapter would reflect individually and collectively in the same or similar line to enhance this trend of thoughts to discover similar constants and constraints in our national and global eco-system and environment.

NB. Indebted to Google for Fig 1-6

Chapter-4

Forest Eco-system Viewed Variously

There can be as many definitions and descriptions on any subject as there are people and organizations defining it; forest is no exception. Any study should have an objective and purposefulness. The purpose of this chapter is to present the various views on forest so that the students of forest-eco-system may form a working definition of their own. This chapter consists of excerpts from FAO (Food and Agricultural Organization), UN (United Nations), FRA (Forward Rate Agreement) and definitions, descriptions and views available from several internet sources. The Indian Council of Forestry Research Institute, Dehradun, Uttarakhand, is the premier institution in the field of forestry research in India is just introduced at the end of this chapter. It is advisable for the students of environment to visit and make a detailed study of the Institute and its activities.

UN Definition of forest

Forest: The UN group basically considers the FAO definition of a forest as the basic one (FAO, 1998; FRA 2000); but acknowledge that many other useful definitions of "forest" exist in published form. The fact that "forest" has been defined in many ways is a reflection of the diversity of forests and forest ecosystems in the world and of the diversity of human approaches to forests. According to FAO/UN a forest is a land area of more than 0.5 ha, with a tree canopy cover of more than

10%, which is not primarily under agricultural or any other non-forest land use. In the case of young forests or regions where tree growth is climatically suppressed, the trees should be capable of reaching a height of 5 meter with a 10 per cent canopy cover.

Forest biome: Forest biome refers to the biodiversity of trees and plants in a forest. There are many types of forests such as tropical, subtropical, temperate and boreal forests each reflecting the characteristics of the climatic variation. They also reflect the ecological and physiognomic characteristics of the trees and plants corresponding to climatic regions of the Earth.

Forest type: Within biomes a forest type may be of specific species of trees like teak forest, Sal forest, coniferous trees forest, sandal wood forest etc.

Forest eco-system: A forest ecosystem can be considered in a number of ways: it is a dynamic complex system of soil, slope, microbes, plants and animals interacting as a functional but natural geographical unit where the humans may or may not have any role. But trees would the central component of the system without even considering the existence of humans. In a forest eco-system trees are at the centre of the eco-system replacing humans in Fig 1 in chapter one on "Basic Ecological Concepts and Concerns" under Environment Management. Humans, with their cultural, economic and environmental needs may become an integral part of any forest-systems.

Forest biological diversity: Forest bio-diversity means the variety of living organisms and their relationship to their nonliving components in the forest eco-system. This implies bio-diversity within and between plant and animal species varying with climate,

altitude, percentage or degree of slope of the terrain, rainfall of the area etc.

Primary forest: A primary forest is a forest, regardless of its age, that has developed as a natural process and never been logged. They may be used by indigenous and local communities living in their traditional sustainable lifestyles. In Europe, primary forest refers to a forest area which has probably been continuously wooded at least for a thousand years. It can be natural or planted; it may be totally unused or partially used by forest dwellers or neighbor-hood people.

Secondary forest: A secondary forest is a forest that has been cleared and has either recovered naturally or artificially. But their ability to sustain the original biological diversity cannot be expected in the immediate future. In Europe, secondary forest is any forest land where there has been a period of complete clearance by humans with or without a period of conversion to another land use. The secondary forests are two types: 1. A naturally recovered or grown after a clear felling, 2. Planted forest after the first clear felling. Over a long period of time the planted forest can become like a natural forest.

Old growth forest: Old growth forests are stands of trees in primary or secondary forests that have developed the structures and species normally associated with old primary forest of that type have sufficiently accumulated to act as a forest ecosystem distinct from any younger age class. For example a coniferous forest will develop again into a coniferous forest after a clear felling, a bamboo forest will continue to be a bamboo forest system, so too a Sal forest system, or a Eucalyptus or pine forest system.

Plantation forest: A plantation forest may be afforested land or a secondary forest established by planting (seedlings or saplings) or by direct seeding. Depending on the purpose, a plantation may be of single or mixed species, of local or exotic species, planted together at one time or at different times, for harvesting forest products or Planted above 33.3% for maintaining a perennial or on less than 33.3% to maintain a temporary forest, for conservation of soil and water or biodiversity or for harvesting forest products. Varying are the purposes of forest plantation.

Degraded forest: A degraded forest is a primary or secondary forest that has lost, through human activities or a fire or even a pest/disease, the structure, function, species composition or productivity normally associated with a forest type expected on that site. Hence, the benefits from a degraded forest will be reduced due its limited biological diversity.

Agro-forest: An agro-forest is a planted or natural forest area within an agro-ecosystem. Thus in a large agricultural area a forest area is maintained around a spring, a pond, a small lake, or on the banks of a stream or river or a rocky or a barren area may be maintained as a forest area, or a residential area may be maintained as forest. When all these are in an agricultural land it is called agro-forest.

Reforestation: Reforestation is the re-growth of forests after a temporary condition of less than 10 years with less than 10% canopy cover due to human or natural intervention.

Aforestation: Aforestation is the conversion a land from other land uses into forest with an increase in the density of trees planted and in canopy cover of each tree.

Forest fragmentation: Forest fragmentation refers to the conversion of formerly continuous forest into patches of forest separated by non-forested lands.

Habitat loss: Habitat loss refers to an individual species losing its habitat to another species of another land usage.

Direct human disturbance: It refers to intentional clearing of forest by any means (including fire) to manage or alter them for any human use.

Forest species: It refers to any living species of microbes, plants or animals that form part of a forest eco-system either permanent or temporary for their survival and development including reproduction.

Native species: A native species is one which naturally exists at a given location or in a particular ecosystem.

Endemic species: An endemic species is a native species restricted to a particular geographic region owing to factors such as isolation or in response to soil or climatic conditions.

Alien species: An alien species or sub-species that has been introduced into another eco-system other than its normal past and present distribution. The definition includes the gametes, seeds, eggs, propagules or any other part of such species that might survive and subsequently reproduce in a new eco-system.

Invasive alien species: An invasive alien species is one which invades another eco-system threatening the native ones though they can be the agent of change.

FAO Definitions:

The following forest and forest related land use classifications are taken from the main report of "*Forest*

Resources Assessment 2000".

Forest: Forest includes natural forests and forest plantations. It is used to refer to land with a tree canopy cover of more than 10 percent and area of more than 0.5 ha. Forests are determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5 m. Young stands that have not yet but are expected to reach a crown density of 10 percent and tree height of 5 m are included under forest, as are temporarily unstocked areas. The term includes forests used for purposes of production, protection, multiple-use or conservation (i.e. forest in national parks, nature reserves and other protected areas), as well as forest stands on agricultural lands (e.g. windbreaks and shelterbelts of trees with a width of more than 20 m), and rubber wood plantations and cork oak stands. The term specifically excludes stands of trees established primarily for agricultural production, for example fruit tree plantations. It also excludes trees planted in agro-forestry systems.

Natural forest: A forest composed of indigenous trees and not classified as planted forest.

Forest plantation: A forest established by planting or/ and seedlings in the process of aforestation or reforestation. It consists of introduced species or, in some cases, indigenous species.

Other wooded land: Land that has either a crown cover (or equivalent stocking level) of 5 to10 percent of trees able to reach a height of 5 m at maturity; or a crown cover (or equivalent stocking level) of more than 10 percent of trees not able to reach a height of 5 meter at maturity; or with shrub or bush cover of more than 10 percent.

Forest change processes

Following are the forest change processes.

Afforestation: Establishment of forest plantations on land that, until then, was not classified as forest. It implies a transformation from non-forest stage to forest.

Natural expansion of forest: Expansion of forests through natural succession on land that, until then, was under another land use (e.g. forest succession on land previously used for agriculture), implying a transformation from non-forest stage to a forest stage.

Reforestation: Establishment of forest plantations on lands which were deforested.

Natural regeneration on forest lands: Natural re-growth of forest plants/trees on deforested lands. This implies growth of new trees/plants and new sprouts of branches from the stems of the trees cut.

Deforestation: Simply means removal of forest trees or long term reduction of the tree canopy cover below the minimum 10 percent. It may be done by humans for some purpose or by the powers of nature like fire, pests, drought, flood, landslides, massive sinking of forest area, sea or water erosion or volcanic eruption. It may imply transformation forest land into another land use pattern. Deforestation includes areas of forest converted to agriculture, pasture, water reservoirs and urban areas. The term specifically excludes areas where the trees have been removed as a result of harvesting or logging, and where the forest is expected to regenerate naturally or with the aid of silvicultural measures. In areas of shifting agriculture, forest, forest fallow and agricultural lands appear in a dynamic pattern where deforestation and the return of forest occur frequently

in small patches. To simplify reporting of such areas, the net change over a larger area is typically used.

Forest degradation: Changes that affect the structure or function of the standing trees negatively and thereby lower the capacity to supply products and services.

Forest improvement: Changes within the forest, which may positively affect the structure or function of the stand or site, and thereby increase the capacity to supply products and/or services.

WCMC / CIFOR Definitions

Under the UN Environment Programme (UNEP), World Conservation Monitoring Centre (WCMC) is a collaboration centre of UN Environment Programme, based in Cambridge in the United Kingdom. The Center for International Forestry Research (CIFOR) is located in Bigor, Indonesia.

Mangroves: Natural forests with >30% canopy cover, composed of species of mangrove trees, generally along coasts in or near brackish or salt water. A total of about 80 species of mangroves are estimated to be there in the world.

Freshwater swamp forest: Natural forests with >30% canopy cover, below 1200m altitude, composed of trees with any mixture of leaf type and seasonality, but in which the predominant environmental characteristic is a waterlogged soil.

Lowland evergreen broadleaf rain forest: Natural forests with >30% canopy cover, below 1200m altitude that display little or no seasonality, the canopy being >75% evergreen broadleaf.

Semi-evergreen moist broadleaf forest: Natural forests with >30% canopy cover, below 1200m altitude in which between 50-75% of the canopy is evergreen, >75% are broadleaves, and the trees display seasonality of flowering and fruiting.

Deciduous/semi-deciduous broadleaf forest: Natural forests with >30% canopy cover, below 1200m altitude in which between 50-100% of the canopy is deciduous and broadleaves predominate (>75% of canopy cover).

Sclerophyllous dry forest: Natural forests with >30% canopy cover, below 1200m altitude, in which the canopy is mainly composed of Sclerophyllous (small, hard, thick) leaves and is >75% evergreen.

Thorn forest: Natural forests with >30% canopy cover, below 1200m altitude, in which the canopy is mainly composed of deciduous trees with thorns and succulent phanerophytes. Phanerophytes are large shrubs and trees in which the overwintering (perennating) buds are located high above the ground. The buds are thus at risk of exposure to drought stress or frost, and such plants occur mainly in regions where frost and drought are uncommon, such as the tropics.

Needle leaf forest: Natural forest with >30% canopy cover, below 1200m altitude, in which the canopy is predominantly (>75%) needle leaf trees like pine, spruce, cedar (deodar), and fir trees.

Mixed broadleaf/needle leaf forest: Natural forests with >30% canopy cover, below 1200m altitude, in which the canopy is composed of a more or less even mixture of needle leaf and broadleaf crowns (between 50:50% and 25:75%).

Lower montane forest: Natural forests with >30% canopy cover, between 1200-1800m altitude, with any seasonality regime and leaf type mixture. Montane ecosystems are found on the slopes of mountains.

Upper montane forest: Natural forests with >30% canopy cover, above 1800m altitude, with any seasonality regime and leaf type mixture.

Sparse trees and parkland: Natural forests in which the tree canopy cover is between 10-30%, such as in the savannah regions of the world. Trees of any type (e.g., needle leaf, broad leaf, palms).

Disturbed natural forest: Any forest type above that has in its interior significant areas of disturbance by people, including clearing, felling for wood extraction, anthropogenic fires, road construction, etc.

Exotic species plantation: Intensively managed forests with >30% canopy cover, which have been planted by people with species not naturally occurring in that country.

Native species plantation: Intensively managed forests with >30% canopy cover, which have been planted by people with species that occur naturally in that country.

Non-tropical forests

Freshwater swamp forest: Natural forests with >30% canopy cover, composed of trees with any mixture of leaf type and seasonality, but in which the predominant environmental characteristic is a waterlogged soil.

Deciduous broadleaf forest: Natural forests with >30% canopy cover, in which >75% of the canopy is deciduous and broadleaves predominate (>75% of canopy cover).

Sclerophyllous dry forest: Natural forest with >30% canopy cover, in which the canopy is mainly composed of scleraphyllous broadleaves and is >75% evergreen.

Evergreen needle leaf forest: Natural forest with >30% canopy cover, in which the canopy is predominantly (>75%) needle leaf and evergreen.

Deciduous needle leaf forest: Natural forest with >30% canopy cover, in which the canopy is composed of a more or less even mixture of needle leaf and broadleaf crowns (between 50:50% and 25:75%).

Evergreen broadleaf forest: Natural forests with >30% canopy cover, the canopy being >75% evergreen and broadleaf.

Sparse trees and park land: Natural forests in which the tree canopy cover is between 10-30%, such as in the steppe regions of the world. Trees of any type (e.g., needle leaf, broadleaf, palms).

Disturbed natural forest: Any forest type above that has in its interior significant areas of disturbance by people, including clearing, felling for wood extraction, anthropogenic fires, road construction, etc.

Exotic species plantation: Intensively managed forests with >30% canopy cover, which have been planted by people with species not naturally occurring in that country.

Native species plantation: Intensively managed forests with >30% canopy cover, which have been planted by people with species that occur naturally in that country.

WRI Definitions

World Resource Institute (WRI) has its own definitions and distinctions on forests. It is a global research non-profit organization established in 1982 with funding from the MacArthur Foundation under the leadership of James Gustave Speth. WRI's activities are focused on seven areas: food, forests, water, energy, cities, climate and ocean.

Frontier forests: Frontier forests are large, relatively intact forest ecosystems. A frontier forest must meet the following criteria:

It is primarily forested. An old-growth forest, also termed primary forest, virgin forest, late seral (partially degraded forest) forest or primeval forest – is a forest that has attained great age without significant disturbance and thereby exhibits unique ecological features and might be classified as a climax community which is an ecological community in which populations of plants or animals remain stable and exist in balance with each other and their environment.

It is large enough to support viable populations of all species associated with that forest type even in the face of natural disasters of a magnitude to occur once in a century.

Its structure and composition are determined mainly by natural events, and it remains relatively unmanaged by humans, although limited human disturbance by traditional activities is acceptable.

In forests where patches of trees of different ages occur naturally, the landscape shows this type of heterogeneity.

It is dominated by indigenous tree species.

It is a natural forest of sizable area harbouring native species of flora and fauna. It is home to most, if not all, other plants and animals that typically live in this forest.

Forest Research in India

The Forest Research Institute is an institute of the Indian Council of Forestry Research and Education and is a premier institution in the field of forestry research in India. It is located at Dehradun in Uttarakhand, and is among the oldest institutions of its kind in the world. It was founded in 1878 as the British Imperial Forest School by Dietrich Brandis. In 1906, it was re-established as the Imperial Forest Research Institute, under the British Imperial Forestry Service. A much larger campus at the present location was acquired in1923. Construction of the new buildings commenced thereafter. Styled in Greco-Roman Architecture by C.G. Blomfield, the main building was inaugurated in 1929 by then Viceroy Freeman Freeman-Thomas, 1st Marquess of Willingdon. Built over 450 hectares, with the outer Himalaya forming its back drop, the building with a plinth area of 2.5 hectares was listed for a time, in the Guinness Book of Records, as the largest purely brick structure in the world. It is now a National Heritage site.

The institute's history is virtually synonymous with the evolution and development of scientific forestry, not only in India, but over the entire sub-continent. The institute has a developed infrastructure of all equipped laboratories, library, herbarium, arboreta, printing press and experimental field areas for conducting forestry research, quite in keeping with the best of its kind anywhere in the world. It is 7 km from Clock Tower, on the Dehradun-Chakrata motorable road. It is the biggest forest based training institute in India. Most of the forest officers are a part of this institute. The FRI's building also houses a Botanical Museum and there are many different kinds of trees brought from around the world.

The Forest Research Institute campus hosts the Indira Gandhi National Forest Academy (IGNFA), the staff college that trains officers selected for the Indian Forest Service (IFS) The museum has six sections like Pathology Museum, Social Forestry Museum, Silviculture Museum, Timber Museum, Non-Wood Forest Products Museum and Entomology Museum. It is a deemed University.

Chapter-5

Ecological Systems: Structure and Types

I. Sub-divisions of ecology

A more detailed study of the four living components of the ecosystem namely microbes, plants, animals and humans need to be undertaken because they play a greater and immediate role in the ecosystem management. Microbiology is the study of micro-organisms which are beneficial as well as harmful to humans though some are neutral. Plant ecology is the study of plants in relation to their environment and in relation to microbes, animals and humans. Among the plants we can study the cultivated and uncultivated plants and under the cultivated we can have many other classifications in agriculture science. Similarly, animal ecology is the study of animals in relation to their environment. However, animal ecology cannot be properly understood without the background of plant and microbe ecology. When animals, plants and microbes are given equal emphasis in ecological studies, the term bio-ecology is used.

As already mentioned the eco-system comprises of the living and nonliving components comprising of soil, water, air, light, heat, micro organisms, plants, animals and human beings. Any of the living being with any of the non-living can form an eco system. They are called natural ecosystems. Some examples of natural ecosystems ate

ponds, lakes, oceans, grasslands, forests, deserts, tundra, river basins, watersheds etc. Thus ecology can be divided into many subdivisions as given in Fig 1 as examples. The students may add on to the list.

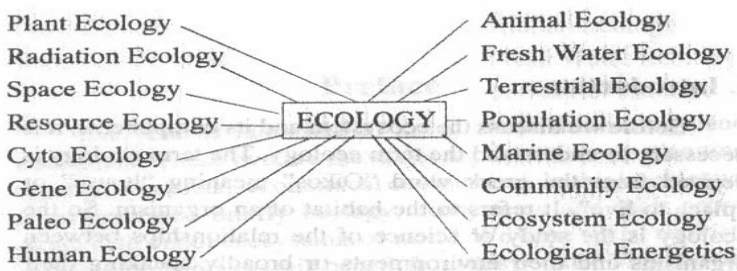


Fig.1: Hypothetical representation of some important sub divisions of ecology. Refer also booklet No. 290 for definitions and descriptions of these terms.

These days, ecology has been contributing very much to socio-economic and political aspects of life. It is so common to find references of ecology in socio-economic writing, magazines, weeklies and daily newspapers. There are interdependencies not only between ecology and other areas of plant sciences, but also between ecology and physical as well as social sciences. The readers and students of ecology may elaborate on this in a session or group discussion.

The various disciplines of science and technology are in a highly developed phase, and are broadening the horizons of our knowledge. But we cannot forget that human life on this earth still depends upon the trapping of solar energy, upon recycling of materials and water through the ecosystem. Many of our social and political problems, that we face now or shall be facing in future such as production of grains, livestock, timber, fibre, fish,

wild life, flowers, control of pest, species, prevention of soil erosion the disposal of wastes, the control of radio active and chemical fallout, deterioration of our habitat, pollution of air and water, etc. are basically ecological problems. To face all these problems it becomes essential that in addition to retain trained ecologists, every person should have some basic knowledge of various principles of ecology. A basic understanding of the ecological systems is necessary for chemists, engineers, town planners, doctors, public health workers, lawyers, administrators, teachers, agriculturists, forest officers or other professionals.

II. Ecology and agro-eco-systems

Ecology gives valuable guidance for the conservation and production management of our natural resources. The importance of ecology can be understood from the fact that it is interrelated to many other disciplines especially horticulture, agriculture, forestry, wild life management, fisheries, space research, atomic research, oceanography, public health, range management, animal husbandry, climatology, geology, geochemistry, environmental physiology, etc. The inter-relationship is as shown in Fig 2.

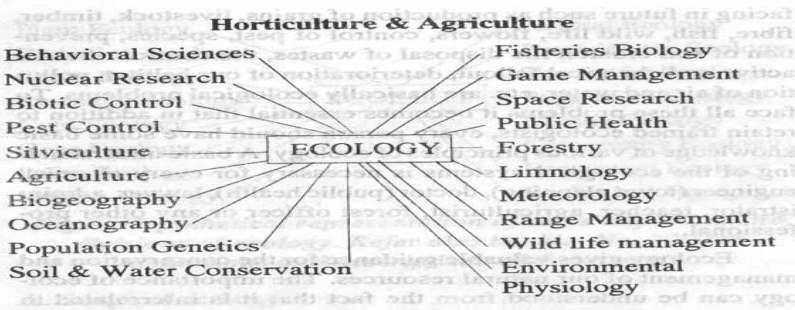


Fig 2: Hypothetical representation showing interdependence between ecology and other ecologically oriented subjects. Refer booklet No. 290 for descriptions of these terms.

III. Kinds of ecosystems

Ecosystems in general are divided into natural and artificial ecosystems which are further divided into sub-eco-systems like natural eco-system and artificial eco-systems. It should be kept in mind that all eco-systems have both **area and volume components** on which humans can operate upon to meet all his needs.

A. Natural ecosystems

These are ecosystems evolved in nature during the course of time. These operate by themselves under natural conditions without any interference by man. Based on the particular kind of habitat, these are further divided in terrestrial, aquatic and space ecosystems.

1. Terrestrial ecosystem: The examples of **terrestrial ecosystem** are forests, grasslands, deserts, arid areas, eroded areas, ravines, mining areas, deforested areas due to natural fire, land slide areas, waste lands, catchment and command areas, snow covered mountain ranges, hilly areas etc. Humans operate both on the terrestrial area and volume.

2. Aquatic may be sea, estuaries, fresh or salt water lakes, rivers, streams, ponds, marshy and low lying areas, rainy season ponds, dams for irrigation and power generation etc. further distinguished into fresh water and marine eco-systems. Humans can operate on both area and volume of the aquatic systems. The aquatic systems may be fresh water and marine/saline water systems.

a. Fresh water bodies

The fresh water bodies may be **lotic** (running water as springs, streams or rivers) or **lentic** (standing water as lake, pond, pools, puddles, ditch, swamp, etc.). Anyone can

easily observe the difference between lotic and lentic water systems even though they are all fresh water eco-systems. Students of ecology should visit few of both lotic and lentic water systems and identify the differences and similarities between them both in the biotic and abiotic factors in them.

b. Marine ecosystem

These are salt or saline water bodies such as an ocean or seas or estuaries etc. Both biotic and abiotic components are different in a marine eco-system compared to fresh water eco-systems. Compare the fresh water and marine water systems in their abiotic and biotic components.

3. Space eco-system: Due to the rapid progress made in space technology during recent years, ecosystems related to space are being studied from various angles. We have both national and international space area and volume. The international space volume/area begins at 100 kilometer and above. We have now sufficient information about space eco-systems in the media both written and televised media, in the internet in the form of write ups and you tubes. We are blessed with such technologies which will take you virtually to those areas of space where we could never think of embarking upon. With the increasing knowledge of space area and volume enveloping earth as a whole or the space volume specific to each country especially with regard to overflying of aircrafts, missiles etc. there are rules and regulations. Man is able influence in a limited way even the space systems also by higher emission of carbon-dioxide, methane and other obnoxious gasses from chemical factories and processing natural resources like leather etc.

B. Artificial ecosystems

These are created and maintained artificially by man

where, by the addition of energy and planned manipulations, the 'natural ecosystems are changed. For example, crop lands, dairy farms, horticulture, cities and urban areas, wild sanctuaries, dams for electric power or irrigation, watershed areas, pasture lands etc. In all these man tries to control biotic and abiotic factors for his own benefit. Wherever man has made some impact on any of the eco-systems the resultant will be artificial. Make a list of artificial eco-systems of various categories such as terrestrial, aquatic and space eco-systems and make a comparative study of them between abiotic and biotic components of the artificial eco-systems of your area. In the future we will be having more and more artificial eco-systems like cities, shopping malls, recreation centres, sports and entertainment systems, institutional systems etc. The electronic and computerized operating systems are making their way into every sphere of human life. With the advent of artificial intelligence in what way the human life and behaviour will change is still to be seen. In the way the computerized technological, electronic automation is going on the human operational capacity is limitless; we have already entered into artificial intelligence era and the **age of cyborgs**. Many of the impacts of human interaction with his eco-system is yet to be seen.

IV. Components of ecosystem

An ecosystem whether it is a pond, forest, desert or the tundra has four components: 1. Non living, 2. Producers, 3. Consumers and 4. Decomposers.

1. Non-living

These are air, water, soil, slope of land, light and heat. The first three consists of the basic elements and compounds known in the inorganic and organic chemistry in the periodic table. These non living substances enter the body of living

organisms, take part in metabolic activities and then return to the environment. The abiotic factors of the ecosystem is again grouped into three parts: (a) The climate regime and physical factors like temperature, relative humidity, light intensity etc., (b) Inorganic substances such as water, carbon, nitrogen, sulphur, phosphorous and so on, which are involved in the cycling of materials in the ecosystem. (c) Organic substances like proteins, carbohydrates, lipids, and humus substances etc. which largely form the living body and link the abiotic and biotic components.

In terrestrial ecosystem, the climate, soil and parent rock material largely determine the diversity of organisms present. At high altitudes, the availability of oxygen is important. In aquatic ecosystems, temperature, salinity, dissolved gases and chemical substances, particulate matter and the nature of sediments determine the species diversity. Climatic conditions and physical factors vary widely from the arctic region to the tropics, and thus greatly affect the distribution of organisms.

2. Producers of autotrophs

Producers or autotrophs are also known as energy transducers which are able to convert solar energy into chemical energy with the help of inorganic substances such as water, carbon dioxide and enzymes. These producers are also known as autotrophic (auto means self, troph means nourishing) organisms which are largely green plants (trees, grasses, crops, tiny phytoplankton, etc.). They possess a green pigment called chlorophyll, which can absorb solar energy and combine it with carbon dioxide and water to produce three carbon triglycerides which then are converted into five and six carbon carbohydrates which are many in number. (the students can make a list of carbohydrates with three, five and six carbon a atoms

and their uses in our everyday life.) The autotrophs are called also photo-autotrophs because they utilize light energy. There are other types of autotrophs, called chemo-autotrophs, which use energy generated in an oxidation reduction process, but their importance in the ecosystem as producers is minimal. Micro-organ-isms like *Beggiotoa (a colourless and filamentous bacteria)* an iron bacteria and sulphur bacteria are examples of chemo-autotrophs.

3. Consumers

Consumers are heterotrophic (hetero =other, trophic = nourishing) organisms, chiefly animals depending on others for their source of food. Depending upon their food habits, consumers may either be herbivores (plant eaters) or carnivores (flesh eaters). Herbivores live on plants. They may be insects, zoo plankton or animals like deer, cattle, elephants, etc. Carnivores consume flesh and usually prey on herbivores and other carnivores. The carnivores may be an insect like a preying mantis or a large animal like a tiger or lion.

4. Decomposers

Decomposers are also heterotrophic organisms but depend upon dead organic matter for their food. They are chiefly microorganisms like bacteria, actinomycetes and fungi. These break down complex organic matter like cellulose, hemicelluloses, chitin etc. found in the plant and animal body, and ultimately release simple substances used by the producers. Some invertebrate animals like protozoa oligochaetes such as earthworms, enchytraeid worms, etc. use the dead organic matter for their food, as they have the requisite enzymes, and hence they are classified as decomposer organisms. Some ecologists feel that micro-organisms are primary decomposers while invertebrates

are secondary decomposers. There may be tertiary decomposers and a fourth one too.

Therefore any recognizable unit of nature can be considered an ecosystem if it includes the four components, namely abiotic factors and biotic factors which are known as producers, consumers, decomposers and the product that is being produced or decomposed.

V. Size of Ecosystem

An ecosystem may be as large as an ocean or a forest or one of the cycles of the elements (nitrogen cycle, phosphorus cycle, carbon cycle etc.) or it may be as small as an aquarium jar containing tropical fish, green plants and snails. To qualify as an ecosystem, the unit must be a stable system in which the exchange of materials follows a circular path. All ecosystems are connected with other ecosystems around them. The ecosystem of the dead log is a part of the ecosystem of the forest, the decomposers of various types and functions acting on it. Different decomposers act on a dead biotic object in succession for a definite period of time acting on different chemicals like carbohydrate, protein, fat etc. and can be classified into different substratum on which they act specifically. All the river ecosystems ultimately mingle gradually into the ecosystem of salt water of sea ecosystem. Thus all the ecosystems on earth are connected and interdependent on each other.

1. Food Chains and Trophic Levels

In nature one organism becomes food for another organism which in turn will also become food for a third organism. The third becomes food for a fourth and this goes on to the last in a chain (Fig. 3). The food chain is also referred to **trophic chain**.

Energy in the form of organic nutrients is transferred

from producers (plants) to consumers (herbivores or carnivores) and then to decomposers as one type of organisms consumes and in turn are eaten by other organisms. This succession is called a **food chain**. The food chain is divided into various trophic levels comprised of all the organisms that obtain their food by an identical number of steps. A given species' population may have one or more than one trophic level according to the source of energy actually assimilated. At each transfer of energy from one generation to another or from one trophic level to another trophic level a large part of energy is degraded or transferred into heat. This heat is used by the consuming or decomposing organisms. Some energy is always dispersed into unavailable heat energy, as no spontaneous transformation can be 100% efficient. The shorter the food chain, or the nearer the organisms to the beginning of the food chain, greater is the availability food energy with higher efficiency.

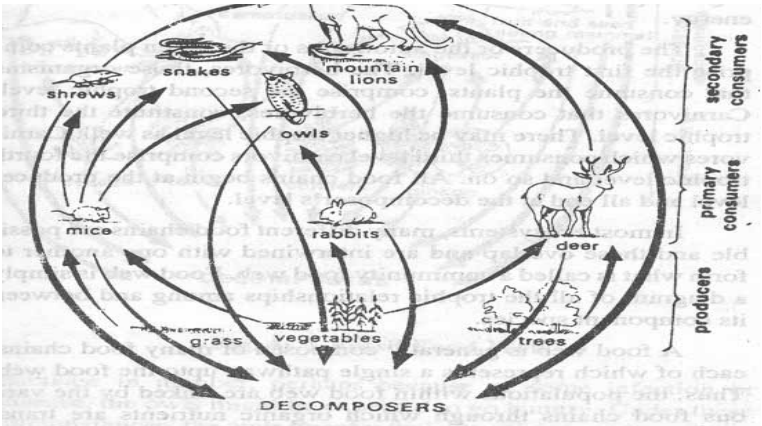


Fig.3 : Food Web

The producers or the autotrophs or the green plants form the first trophic level. The herbivores, those organisms that consume the plants, comprise the second trophic level. Carnivores that consume the animals constitute the third trophic level. Those which consume all types are called omnivores. As shown in Fig 3 the diagram is divided into four types: decomposers, producers, primary consumers, secondary consumers; but ultimately all of the groups become prey to decomposers. All food chains begin at the producer level and all end at the decomposer's level.

In most ecosystems, many different food chains are possible and they overlap and are intertwined with one another to form what is called a community food web. Food web is simply a diagram of all the trophic relationships among and between its component species.

A food web is generally composed of many food chains, each of which represents a single pathway up to the food web. Thus, the populations within food web are linked by the various food chains through which organic nutrients are transferred. Any alternate pathways in a food web help to maintain the stability of the living community. If the rabbits in some area have reduced threat to life they will have a better chance to increase their number. Greater the number of alternate pathways a food-web has more stable will be the community of living components which make up the web. Beginning with any organism we can trace this food chain cycle backwards or forwards.

A possible fossil food web of about 150 million years ago is illustrated in figure fig. 4. This food web indicates the green plants as producers and animals as consumers. The decomposers are largely missing as fossil but we assume that bacteria and molds existed then too. Otherwise, the balance of nature could not have been maintained.

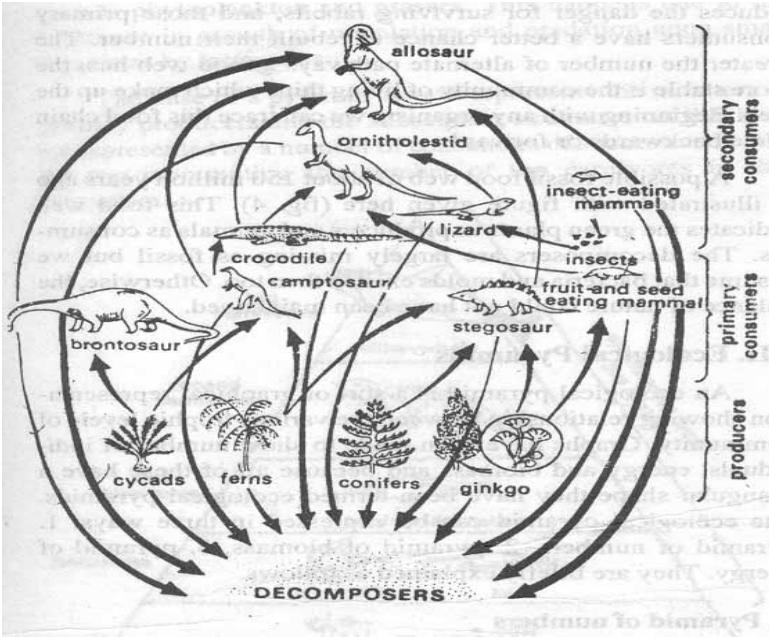


Fig. 4: A Fossil Food Web

Exercise: *list out the organisms living in your area and prepare a producer, primary consumer, tertiary consumers as man and finally all falling back to the decomposers. Also make a general study of the decomposers.*

2. Break downers, Decomposers & Purifiers

a. Break downers are certain types of insects and fungi that act on dead materials before micro-organisms begin to act. They are common decomposers in a variety of ecosystems. You can explore more specific species examples to see how different types of beetles or worms, for example, break down dead matter.

b. Decomposers are those organisms which help to decompose any living organism during or after its life. Many insects and worms eat the living and growing

parts of plants and the decomposition mostly taking place in their guts where the decomposition continues at another level by decomposing microbes residing in the guts. Thus all herbivores are in the chain of decomposers. In vertebrates, five stages of decomposition are typically recognized: fresh, bloat, active decay, advanced decay, and dry or skeletonized.

c. Putrefaction is the decay of the organic matter by the action of micro-organisms more in the presence of air, resulting in the production of a foul smell. It occurs between 10 to 20 days of the death of an organism. Putrefaction involves the decomposition of proteins, breakdown of the tissues, and liquefaction of the organs by bacteria. Putrefaction is the fifth stage of death, following pallor mortis, algor mortis, rigor mortis, and livor mortis. Livor mortis means pooling of blood to one area.

However in the following examples distinction between break-downers, decomposers and putrefies are not maintained.

Examples of Decomposers in Oceans

There are more decomposers in tropical oceans, like the Pacific, because of the warmer temperatures. Most marine decomposers are bacteria.

Christmas tree worm: uses feathery appendages to catch organic matter floating in the water.

Crab: saltwater crabs are considered scavengers who eat any edible matter they find.

Granulated sea star: moves along rocks and other stationary surfaces and cleans up dead organic matter.

Hagfish: while these eel-like creatures do sometimes hunt, they are mostly scavengers who can sit inside a dead carcass and absorb the nutrients from it.

Sea urchin: these spiny creatures are both consumers and decomposers because they scrape organic matter off rocks to feed on it.

Tube worm: this deep sea creature depends on the waste made by bacteria inside its body to live.

Examples of Decomposers in Freshwater

Freshwater decomposers are mostly bacteria and are typically found at the bottom of lakes, ponds, or rivers.

Mildew: type of bacteria found in or near water,

Trumpet snail: this type of snail is a scavenger sometimes considered a pest,

Water mold: type of bacteria found in freshwater or wet soil,

Yeast: type of bacteria found in freshwater lakes.

Examples of Decomposers in Terrestrial Ecosystems

Terrestrial decomposers live on land in all different types of ecosystems. The dead plants and animals they consume are called detritus.

Examples of Forest Ecosystem Decomposers

Decomposers in the forest are typically found on the forest floor.

Beetle: type of shredder that eats and digests detritus,

Earthworm: type of shredder that eats and digests detritus,

Millipede: type of shredder that eats and digests detritus,

Mushroom: type of fungi that grows out of the ground or the dead material it's feeding off,

Pillbug: type of shredder that eats and digests detritus,

Saprobe: microscopic organisms that live in soil; bacteria are a type of saprobe,

Slime mold: type of saprobe that grows on damp rotten wood and rotting leaves,

Slug: type of shredder that eats and digests detritus,

Snail: type of shredder that eats and digests detritus.

Examples of Desert Ecosystem Decomposers

You won't find many decomposers in deserts because they typically like moist areas, because moisture is a common environment for decomposition; Many of the desert decomposers you can find are insects.

Dung beetle: insect that feeds off animal feces,

Fly: insect that feeds off decaying materials,

Millipede: arthropod that feeds of decaying plant material,

Saharan silver ant: fast ants who thrive in deserts and feed off things like animal & carcasses.

Examples of Grassland Ecosystem Decomposers

Grassland decomposers can sometimes be found in forests or deserts since those are similar environments.

Acidobacteria: type of bacteria that thrive in savannas,

Termite: insect that breaks down cellulose from dead wood,

Turkey tail mushroom: fungus that grows on and feeds on dead logs.

Examples of Mountain Ecosystem Decomposers

Mountain decomposers are sometimes found in forests too, since they can be similar environments.

Bolete mushroom: fungi that feeds off the byproducts of the ponderosa pine tree,

Mountain pine bark beetle: insects that feed on dying and dead trees,

Purple fairy fingers: type of fungus that feeds of decaying trees.

VII. Ecological Pyramids

An ecological pyramid is a sort of graphical representation showing relationship between the various trophic levels of community. Graphs have been made to show number of individuals, energy and biomass and because all of these have a triangular shape they have been termed ecological pyramids. The ecological pyramid can be expressed in three ways: 1. pyramid of numbers, 2. pyramid of biomass, 3. pyramid of energy. They are briefly explained as follows.

A. Pyramid of numbers

It is observed that in most food chains, the number of organisms decrease in each succeeding stage a large number of small animals occur at the base, a few large ones at the top (Fig. 5). The pyramid may be upright or inverted depending upon the size of the producers in the community. Large producers such as the oak tree, will be fewer in number than the smaller organisms, such as phytoplankton and grasses. This happens due to the difference in growth of population and predation upon small organisms by large ones.

The base of a pyramid always represents the numbers of primary producers and the subsequent structures on this base are represented by a number of consumers of successive levels, the top representing the number of top carnivores in that ecosystem.

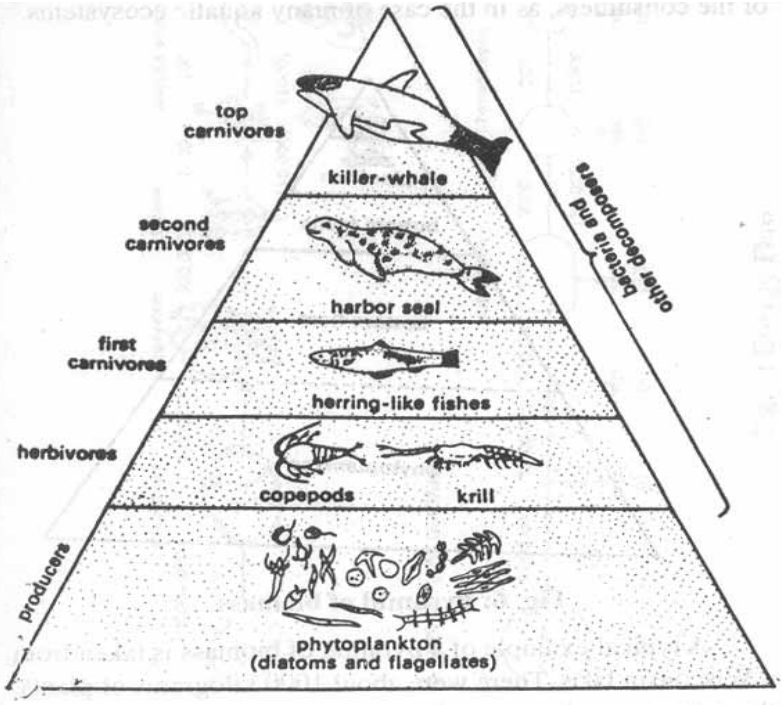


Fig. 5: Pyramid of Numbers

B. Pyramid of biomass

Biomass refers to the total weight of dry matter or caloric value present in the ecosystem at anyone time. The pyramid of biomass (Fig. 6) can be prepared by using the weights of the organisms in the different trophic levels. The biomass of a single tree is naturally very high than the biomass of a number of birds feeding upon the tree. The biomass pyramid may be inverted if the turnover rate of the producers is much more rapid than that of the consumers, as in the case of many aquatic ecosystems.

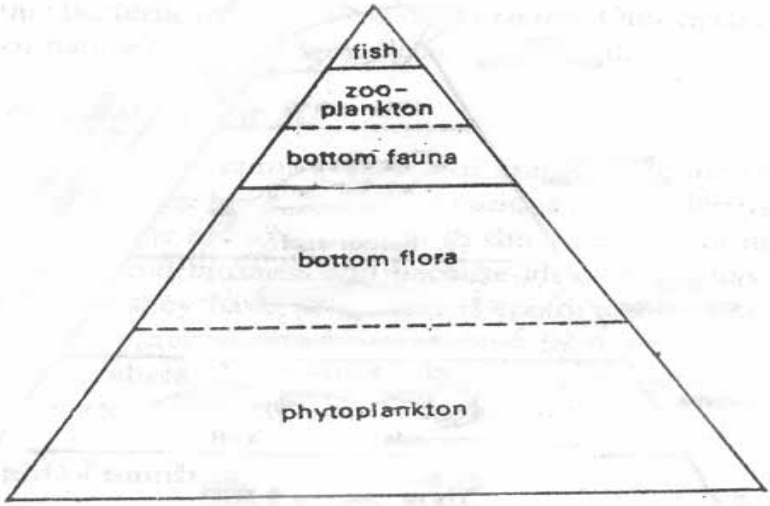


Fig. 6: Pyramid of Biomass

A typical example of a pyramid of biomass is taken from a Wisconsin lake. There were about 1000 kilograms of plants, the primary producers per hectare, there were about 114 kilograms of animals per hectare on the second trophic level and about 38 kilogram of animals on the third major trophic level.

C. Pyramid of energy

The pyramid of energy (Fig 7) represents the total amount of energy utilized by different trophic level organisms of a ecosystem in unit area over a set period of time in linear models. Towards the end of the line least energy is needed. We can also depict the same in pyramidal ways on the basis of the energy utilized or needed.

The diagram depicts the amount of energy-flow to each successive trophic level in a community. Because energy is always lost in transfer, each successive trophic level receives less energy than the level before or below. Greater

amount of energy is available at the producer level than at the consumer level. The energy production of the primary consumers is greater than that of the secondary consumers. The energy at the tertiary consumer level is produced in minimum level. Thus, the producer level always forms a wide pyramid base and successive levels narrow to an apex at the highest trophic level.

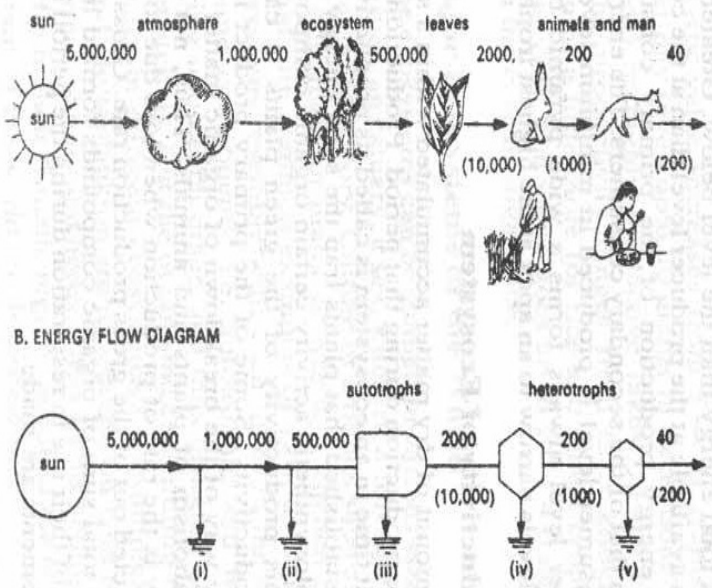


Fig. 7: Energy Flow

VIII. Productivity of Ecosystem

The amount of dry matter accumulated within a specified period is the production during that period. Production per unit area per unit time in an ecosystem is called its **productivity**. It is now well established that plants trap the solar energy and due to their photosynthetic activity

certain organic compounds are formed. This productivity of the green plants is called the primary productivity. Some of the primary product is all the time lost by way of the breakdown of organic matter in respiratory metabolism of plants and animals. Thus, net primary productivity is the rate of production when loss due to respiration is deducted out of the gross production rate. Gross productivity is the total sum of organic compounds formed including the amount of their use in respiration during the period in which the measurements are made.

Primary productivity refers to total increase in weight in all parts: fruits, leaves, stems, roots, etc. as against agricultural productivity which refers to useful parts as grains or fodder parts. The efficiency of any ecosystem greatly depends upon the production rates of its primary producers. Oceans form the largest ecosystems and their productivity varies in different climatic regions. In deep sea the productivity is about 0.5 gram/sq metre/day, and on the shores it may be 2 to 3.5 grams. The productivity value increases from 5 to 10 grams per square meter per day (even up to 50 grams in exceptionally favorable conditions) in highly productive lakes. In the case of crop plants the productivity ranges from 0.25 kilograms to 1.0 kilogram or a little more for rice and wheat crops per square meter per year. The value goes up to 2.0 - 4.0 kg per square metre in the case of sugar cane.

IX. Major Ecosystems of the World

The ecosystems can be studied in various sizes: a pond, a lake, a river, an estuary, a sea, a desert, a forest, a grass land, a coral reef, a laboratory etc. Culture of animals such as protozoa, a field of sugarcane or maize or wheat, a kitchen garden and a space craft are common examples of various ecosystems. AIl the ecosystems resemble with

each other in the sense that all have same components, i.e. autotrophic and heterotrophic, interacting upon each other, and thus bringing about circulation of materials. But the organisms constituting these components, vary in different ecosystems for example, in pond the algae and phytoplankton are producers, on land these producers are trees, shrubs and herbs. The various ecological systems also differ in their climatic regime. Some of the most important ecosystems of the world are described here.

A. Land ecosystem

A cropland ecosystem is a man made ecosystem. Man has been doing his best to modify this ecosystem for his own benefit. A crop land ecosystem may be illustrated by all kinds of crops like wheat, maize, rice, sugarcane, fruit trees, flower plants etc. It has the following components besides the abiotic factors such as carbon dioxide, water, oxygen, nitrogen and other elements and compounds.

1. The primary producers

These are the main plants of the crop and weeds growing with main crops. Such as wheat, maize or paddy crop levels and their weeds.

2. The consumers

The first order consumers, i.e. herbivores, in the crop land ecosystem are represented by insects (e.g. thrips, aphids, bugs, ants, etc.) rats, rabbits, birds, animals and man. The second and third order consumer: i.e. carnivores are represented by frogs, snakes, birds such as hawk etc.

3. Decomposers and transformers

Bacteria and fungi like Bacillus, Clostridium, Pseudomonas and Helminthosporium etc. are common

decomposers and transformers of crop land ecosystem. Both the producers and consumers are decomposed by various kinds of microorganisms.

B. The pond ecosystem

The pond beautifully illustrates a self sufficient and self regulating ecosystem. The life span of ponds ranges from a few weeks or months in the case of small seasonal ponds to several hundred years for larger ponds. If a bottle of pond water is analyzed it is found to have a mixture of living organisms, both plants and animals, and inorganic and organic compounds. The two components, namely autotrophic and heterotrophic components are in perfect harmony in a pond. The different components of a pond ecosystem are as follows.

1. Abiotic substances

The abiotic substances are basic organic and inorganic compounds such as corbondioxide, water, oxygen, nitrogen, phosphorus, calcium, amino acids, humic acid etc. Only a small amount of these substances is available to the producers' (plants) in the form of solution. Major amount of these abiotic substances remains as reserve in the bottom sediments and some part of them also remains inside the bodies of animals. The rate of release of these abiotic substances depends upon solar input, cycles of temperature and climatic regimes.

2. The primary producers

In a pond, the producer organisms are of two types: (i) rooted (emergent, submerged and floating) and (ii) non rooted producers. The rooted producers may form three zones, viz. (a) The zone of emergent vegetation (b) The zone of floating vegetation and (c) The zone of

submerged vegetation. The common rooted producers in pond are Ocillatoria, Spirogyra, Chara, Hydrilla, Azolla, Utricularia, Vallisneria, Lamnea, Ceratophyllum, etc. the non-rooted producers, comprise phytoplankton, such as Volvox Euglena, Algae, etc. Phytoplankton is distributed throughout the pond as deep as light penetrates. Phytoplankton, play a significant role in the production of food. This constitutes the autotrophic component of pond and life of heterotrophic components (animals, bacteria and fungi) depends upon it.

3. The consumers

The consumers in the pond are represented by various larvae and nymphs of insects belonging to the order Odonata, Placomptera, Ephemeroptera, Trichopetra and Coleoptera and adult insects like Nepa, Notonecta, Ranatra, Lithocerus, Corixa and certain beetles. Other common consumers include rotifers, crustaceans (e.g. Daphnia, Eyclops, etc.) leeches, molluscs, fishes (e.g. Calla, Barbus, Labeo, Notoperus, etc.) frogs and larger carnivorous fishes.

4. The decomposers and transformers

These are represented by various bacteria, flagellates and fungi. These are distributed throughout the pond but are specially abundant in the soil. When temperature conditions are favourable, decomposition occurs rapidly in water. The dead organisms are broken down into pieces, consumed by the combined action of detritus feeding animals and micro-organisms and their nutrients released for reuse.

It may be noted that animals and plants living in ponds are always under stress. The daily fluctuations of temperature, corbondioxide and oxygen are felt greatly in pond. Though plenty of water is available to animals

and plants, yet those living in temporary ponds have the danger to face drought conditions and hence have certain morphological and physiological adaptations to meet this change.

C. The ocean ecosystem

The ocean is the largest and most stable ecosystem. The major oceans viz. Atlantic, Pacific, Indian, Arabic and Antarctic and their extensions cover approximately 70% of earths surface. The oceans existed before the life on this earth began, though they have expanded and contracted in different geological periods, but they have provided continuous medium both in space and time for the organisms. These oceans provide 300 times more space to the organisms as compared to the space provided by terrestrial habitat. The life in the ocean, as in other ecosystems depends upon light. The environment in the ocean is more stable in chemical composition (salinity, temperature, oxygen and water) the ocean ecosystem may be described as follows:

1. The primary producers

The primary producers in the open sea are phytoplanktons, mostly diatoms but green flagellates (dinoflagellates) also play a significant role. Diatoms, dinoflagellates, a few microscopic algae, large floating weeds and green brown and red algae are the basis of all other life in the sea. All those producers are present in the photic zone. The photic zone, also called the euphotic or limnetic zone, is the part of a lake or ocean where the rate of photosynthesis is greater than the rate of respiration by phytoplankton. Phytoplanktons are microscopic plants living suspended in the water column that have little or no means of motility.

2. The consumers

The consumers (macro consumers) comprise of crustaceans, molluscs, herbivorous, fishes and carnivorous fishes such as Mackerel, Herring, Shad, Basking, Shark, etc. The secondary carnivores in the food chain are fishes, such as Cod, Haddock, Halibut, etc. which are bottom feeders. Two characteristics of open sea fishes are important, viz. their tendency to remain together (called "schooling") and seasonal migrations. Knowledge of these are made use of in commercial fishing operations.

3. The decomposers

The decomposers in sea are bacteria. Their count ranges from less than one per litre to a maximum of 10 per milliliter in sea shore. The excreta of the living organisms and the dead bodies of plants and animals from every link of the food chain undergo decomposition by the action of marine bacteria. The material is then attached by transformers and converted to suitable forms for the nutrition of green plants once again.

D. The forest ecosystem

About 30 per cent of the land is occupied by forests. Where sufficient moisture is available and where temperature is not too low that area of land is occupied by forests. Depending upon factors like temperature, available water and soil conditions, and the forests can be classified into four major types each having its own characteristic flora and fauna. They are: 1. Tropical forests, 2. Subtropical forests, 3. Temperate forests and 4. Alpine forests.

All these four types of forests can be found in the Himalayas. The components of a forest ecosystem are as follows.

1. Primary producers

As obvious, the primary producers in forest are trees, which may be angiosperms or gymnosperms. The trees in the tropical evergreen forests are broad-leaved and the leave fall is irregular. Whereas in temperate deciduous forests, and in deciduous forests, we find pines (e.g. Pinus) with needle-like leaves, which falloff during dry season. In tropical forests, the trees are with broad leaves which obstruct the light from reaching the ground. Thus only shade tolerant species bamboos, ferns and shrubs survive at the lower level of the forest. The other two characteristic forms of tropical evergreen forests are the vines and epiphytes. In India, tropical evergreen forests are found along Western Ghats, Kerala, NEPA and nearby areas.

2. The consumers

The macro-consumers (animals) in different forests are also very different and well adopted for the conditions of that life. We find foliage arthropods such as ants, flies beetles, leaf hoppers, bugs and spiders. Moles, squirrels, shrews, flying foxes, fruit bats, mongooses, etc. are also present.

3. The decomposers

The soil animals found in the forest are certain protozoans, flat worms, nematodes, annelids, snails, millipedes, centipedes, spiders, spring tails, termites, thrips and ants. The role of decomposers is played by some of the soil animals and soil bacteria found in the soil.

The different types of forests also vary in their gross productivity. The productivity is highest in the tropical evergreen forests due to stable environment, large availability of water and high constant temperature.

E. The grass land ecosystems

The grass lands occupy about 19 per cent area of land. The approximately occupied area is 20,000,000 sq. km scattered allover the world in the tropical, temperate and alpine regions. Grass lands generally occur in the regions with yearly rainfall between 25 -75 centimeters. The principal grass land ecosystems of the world are the great plain of Canada, USA, S. Argentina to Brazil and S. Asia to Central Asia. In India grass lands are found on the tops of Nilgiri Hills. As compared to forests, in grass lands, there are greater variations of temperature, moisture, wind, intensity of sunlight and fewer places for animals to retreat. Human activities have chiefly affected the grass lands all over the world and as a result much of the area has been converted into culturable land.

However, the intense biotic activity and potential production of grass land have attracted the attention of ecologists all over the world. All efforts are being made for the proper understanding and management of the grass land ecosystems in all the countries.

1. Abiotic substances

The earth, along with the atmosphere, is a store house of all elements which enter into the body compassion of the living organisms. The various elements required by plants are unevenly distributed in the soil. The carbon, hydrogen, oxygen, nitrogen, phosphorus and sulphur required by plants are respectively supplied by carbon dioxide, water, nitrates, phosphates, and sulphates respectively. Besides, the plant body also requires major elements like potassium, sodium, calcium, iron, etc. and trace elements like boron, copper, zinc, cobalt, molybdenum, vanadium, etc. which are also supplied by the soil.

2. The primary producers

The primary producers are chiefly the members of Graminae family and a large variety of crops. Scattered shrubs and trees also helps in production.

3. The consumers

Herbivores, mostly mammals, birds and insects are dominant consumers. The insects most commonly found include Leptocorisa, Dysdercus, Oxyrhachis, Cicindela, Coccinella, termites (Macrotermes), etc. The millipedes and reptiles (e.g. Calotes versicolour) are also common consumers.

4. The decomposers

The decomposers include various bacteria, moulds and fungi. The common moulds are Mucur, Aspergillus, Eladosporium and Rhizomes. The activity of decomposers is maximum in wet monsoon season.

F. The desert ecosystem

The deserts occupy 17 per cent area of total land and occur in the regions with less than 22 cm of annual rainfall. The great deserts of the world occur on all the continents except Europe and Antarctica. Important deserts are the Sonoran Desert (America and Mexico), the Sahara (North Africa) and the Thar Desert (India). The Central portion of Australia is also a desert. Extreme desert is arid wasteland, with practically no vegetation. In the ecological sense, however, deserts also include arid regions which contain considerable vegetation in the form of bushes, shrubs and trees, especially adopted to tolerate hot and dry climates.

1. The primary producers

The shrubs, bushes and trees are the main producers

in deserts. The various bushes and shrubs are generally isolated. These shrubs and bushes have shallow, wide-spread and highly branched root system, adopted to absorb any surface moisture. Stems and branches often bear prickles and thorns which may be reduced leaves (an adaptation to check transpiration of water from leaves). Some succulent cacti are also found. These store a large amount of water in their stems as a reserve for use when there is no water in the soil. The desert plants have adaptation to retard transpiration and survive long periods of drought. Microflora such as mosses, lichens and blue green algae are also found. These remain dormant in the soil but are able to respond quickly to cool or wet periods.

2. The consumers

Since primary producers are very less, the amount of food available to the animals is also very low. So only a few animals (consumers) are found. The most common consumers are reptiles and insects. These are able to live in the deserts because of their impervious integument and dry excretions which enable them to get along on the small amount of water produced due to metabolism. Except a few species, mammals are-poorly adopted. Some nocturnal rodents are present. Some birds are also present. The camel, called the 'ship of the desert' is able to store water in its body. Large animals including carnivores are relatively scarce. The various desert animals have various adaptations in their morphology and physiology which enable them to live in such an environment.

Thus, we find that water and high temperature are main limiting factors in deserts for plants and animals. Irrigation can convert deserts into some of our most productive agricultural lands. Along with irrigation, man also has to think of stabilizing biochemical cycles and energy flow at

new increased rates to get high productivity permanently from such lands. This is being practiced in Rajasthan in India.

G. Estuarine and sea shore ecosystem

The word 'estuary' refers to a river mouth or coastal bay where the salinity is intermediate between the sea and the fresh water. In this region tidal action plays a very important role. This is a regions of maximum stress. The physical factors like salinity and temperature are much more variable. The salinity varies from 0.5 -35 per cent. But there is abundance of food, due which this region is very rich in fauna. Among the shore live thousands of well adopted species that are not found in the open sea, on land or in fresh water. Echinoderms, Cephalopods and Molluscs are completely absent in estuarine ecosystem.

The important estuaries in India are Hooghly -Malta estuary (West Bengal), Adyar estuary (Madras), Chilka lake (Orissa) and Pulicat Lake (Tamil Nadu and Andhra Pradesh). Of these the largest estuarine system is represented by Hooghly-Matla estuary. It covers an area of 8029 sq. kilometers comprising of the major portion of the Ganges and Brahmaputra delta. In this estuary, there are no thermal variations, but variations in salinities are very wide ranging from traces to 33.75 per cent. The flora and fauna of this estuarine system include several species of diatoms, such as Rhizostoma, Biddulphia, Hemidiscus, Chetoceros, Triceratium, etc.; green algae like Spriogyra, Eudorina, Closterium, like Oscillatoria, Anabaena Microcystis, etc. The protozoans present mainly include Euglena, Ceratium, Noctiluca, Diffugia, Arcella and Vorticella. A large number of crustaceans and rotifers are also present along with above pelagic forms. The benthic fauna include annelids (Tubiflex), small prawns, gastropods and fish larvae.

H. Seashore ecosystems

1. Rocky shore

Rocky shore is characterized by constant erosion due to wave action. The waves move towards shore carrying rocks and small pebbles with them and throw them on the shore. The rocks offer a solid substrates for the attachment. The rocky shores have an abundance of sessile animals such as Patella, Haliotis, Oysters, Barnacles, Tunicates, Spongs, Coelenterates, etc.

2. Sand beach

It is characterized by a population mainly of crabs. The greater part of coastline in India is sandy.

3. Intertidal mud flat

It is visible only during low tide. It supports avery1arge population of shell-fish marine clams, gastropods and other .animals. The primary producers are algae found on and in the mud.

4. Tidal estuary

It is generally dominated by salty marshes, and has a number of shallow creeks. These shallow creeks and salty marshes support an abundance of stationary organisms. These also serve as nursery grounds for shrimps and fishes. The estuaries and inshore marine waters are among the most fertile natural ecosystems of the world. The following factors account for their high fertility.

a. The tidal action brings rapid circulation of nutrients and food and also helps in the removal of waste products at a rapid rate

b. The major type of autotrophs work together to maintain high gross production rate. These autotrophs

are phytoplanktons, microflora (e.g. algae in and on mud, sand, rocks, etc.) and large attached plants (e.g. sea weeds, submerged grasses and marsh grasses).

c. There is an year round production by succession of 'crops'.

d. There is close contact between autotrophic and hetero trophic layers.

X. Conclusion

The major ecosystems of the world are briefly described in this chapter. However, one should not forget the whole world itself is an ecosystem and it is beyond the scope of this chapter to explain all its components and their inter relationships. Ecosystem is a complex system of relationships of interdependences forming a web of food chain and energy transactions. It is also a system of complex dynamic and evolutionary process that is taking place in myriads of cyclic process. Ecology is the science of ecosystem or the nature. It comprises all the known disciplines in physics, chemistry, biology, mathematics and social sciences. Ecology looks at the nature through these sciences from a focal point.

Chapter-6

Atmospheric Environment

Atmospheric environment of the earth is as dynamic as any other component in the ecosystem such as soil, plant kingdom, animal kingdom. The length of the **days** and **nights**, day to day **weather** change, **climate** and **seasons** are the five main factors that come into our mind when we think about the atmospheric influence on environment. **Day and night** occurs due to earth's rotation around its axis. **Weather** refers to the day-to-day changes in the temperature, humidity, sunshine, clouds, rainfall, snow fall, wind speed, atmospheric pressure etc. **Climate** refers to the weather conditions prevalent in a place or region over a period of time whereas **Season** refers to a stable climate and weather stage for a few months. Seasonal change is due to the apparent, back and forth, year after year movement of the sun between the tropic of cancer in the north and the tropic of capricorn in the south as shown in Fig 1. This apparent movement is due to two factors of the earth itself: earth's tilt of 23.5 degree on its axis and its orbiting movement around the sun. The tilt of the earth, the sun shined areas and the length of days at Arctic Circle, tropic of cancer, equator, tropic of capricorn and Antarctic Circle are also given in Fig 1.

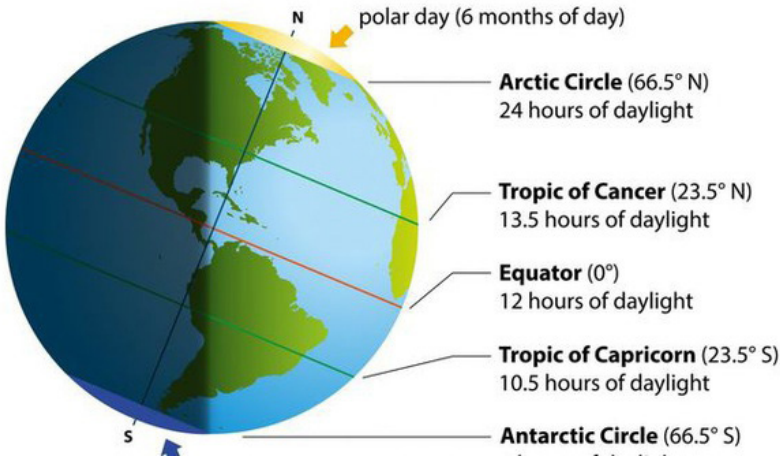


Fig 1 Day and night difference in length

The apparent movement of the sun between the two tropics cause the gradual changes in the lengths of day and night; when the sun comes in line of equator the length of the day and night will be equal as shown in the figure; similarly the day length at different key positions are also given in Fig 1. Variations in the length of the day and night have a great influence on all living beings like plants, animals and humans. We have four seasons such as spring, summer, fall, and winter; however this seasonal variations may not be very clearly distinct everywhere. For example in the tropical/torrid region the seasonal variations may not be clearly distinct whereas in certain parts of the temperate regions like England the four seasons are distinctly clear. The day-to-day weather change, climatic and the seasonal variations in different locations in the world are due to changes in the humidity and intensity of rainfall, height of locations, intensity of sunshine, amount of clouds, amount

of charged atomic particles (ions) in the clouds, level of atmospheric pressure, speed and direction of air movements, presence and intensity of plants and forests on the earth, etc. In short there are many factors that are responsible for numerous changes in the atmosphere and are influencing the earth's eco-system. Above all atmospheric changes are determinants of the type of agriculture and animal husbandry practices followed by the people in different parts of the world.

The extent of forest cover and the weather conditions influence on each other. Forest cover of an area enhances high humidity in the air facilitating more precipitation which in turn improves the forest cover and the water holding capacity of the soil which in turn enhances the biodiversity of the area which in turn enhances the ecological and economic conditions of an area. Thus goes the chain of influence of one factor on other factors. Since every component in an eco-system is interconnected, change in one alone can affect the weather and climate of that eco-system. The key factor that influences the weather and climate of a place is the moisture content in the form of humidity in the air volume of that area. Depending on the temperature and pressure in the atmosphere, the moisture in the atmosphere may precipitate in the form of rain, hail stones or snow. The temperature variation depends also on the latitude and the height of the location. Hence rainforests are mostly located in the tropical plain regions; temperate forests are located in the temperate or high altitude region whereas boreal forest are seen in areas covered with snows more than six to eight months a year. Hence we have various types of forests called tropical forests, subtropical forests, temperate forests and boreal forests; accordingly the animal populations and human life styles vary from place to place.

Earth Atmosphere

The total thickness of earth's atmosphere in five layers is estimated to be 1000 kilometers; however the major part of it is limited to the lower most layer of 16-20 km having maximum air pressure which decreases with increasing altitude. The five main layers of the atmosphere are troposphere, stratosphere, mesosphere, thermosphere and exosphere without any distinct boundary between them nor the exosphere and the outer space. However an imaginary line called Karman line is fixed by the scientists at about 100 kilometers from the surface of the earth. Fig 2 depicts the five main recognized layers of atmosphere. However there may be variations in the thickness of different layers notified by different information sources.

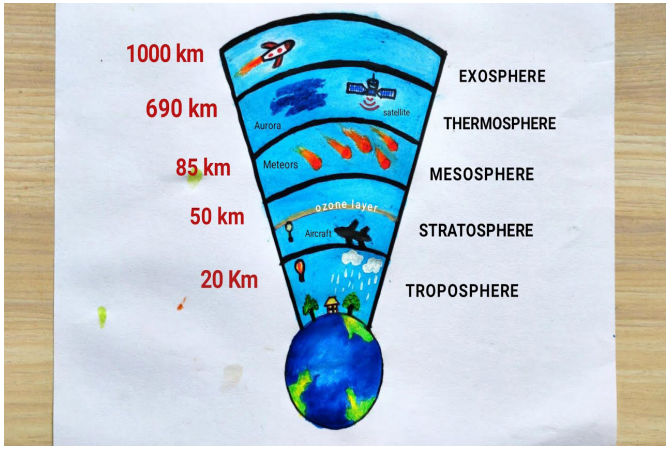


Fig 2 Layers of atmosphere

Starting from the ground level the lowest layer of our atmosphere is **troposphere** extending up to 20 kilometers above sea level. We humans live and operate in the troposphere, and nearly all weather conditions occur in this layer. Ninety nine percent of the water vapour in the atmosphere is present in this layer and most of the clouds appear here. Both air

pressure and temperature drops steadily as one goes up in the troposphere. All forms of climate changes which affect all living beings takes place in this sphere.

Stratosphere the next layer extending up to about 50 km harbors the ozone layer (at around 35 km height) which absorbs high-energy ultraviolet rays from the sun augmenting the temperature making stratosphere warmer due to less of turbulence and updrafts found in the troposphere. Hence most commercial passenger jets fly in the lower stratosphere to have a smoother ride.

Mesosphere the third layer extends upward to a height of about 85 km where most of the meteors get burned up saving the earth from their deadly impacts. The temperature in this layer is relatively colder than stratosphere. The air in mesosphere is too thin to breathe and the atmospheric pressure fall well below 1% of the pressure at sea level and it continues dropping as you go up higher and higher.

The next layer is called **thermosphere which absorbs h**igh-energy X-rays and UV radiation from the sun raising its temperature to hundreds and thousands of degrees. The height of this layer varies between 85 to 690 kilometers. However, the air in this layer is so thin that one would feel freezing cold. Many satellites actually orbit the earth **within** thermosphere. Variations in the amount of energy coming from the Sun exert a powerful influence on both the height of this layer and the temperature within it. The aurora of the Northern Lights and Southern Lights occur in the thermosphere.

The topmost layer is called **exosphere** ranging between 690 to 1000 kilometers and the air in this sphere is so thin making it more space-like as there is no clear-cut upper boundary where the exosphere ultimately fades away into space.

Beyond exosphere many scientists consider another layer called ionosphere, where due to high energy radiation from the sun, has knocked electrons loose from their parent atoms and molecules. Such electrically charged atoms and molecules formed in this way are called ions and hence this sphere is called ionosphere.

Composition of Air

Air sampling is done at the height between 3-10 meters from the ground within the troposphere the lowest layer of atmosphere of the earth. Here the air is made up of approximately nitrogen (78.084%), oxygen (20.946%), carbon dioxide 0.01 to 0.1, ozone ranging from 0 to 0.0.01%, sulphur-dioxide 0 to 0.0001%, nitrogen dioxide 0 to 0.000002%, argon (0.934%), neon (0.0018%), helium (0.000524%), methane (0.0002%), krypton (0.000114%), hydrogen (0.00005%), nitrous oxide (0.00005%), xenon (0.0000087%) etc. Water vapour varies 0-7%. This composition of the air is maintained uniformly due to the constant mixing associated with atmospheric movements; but at a height above 90 km diffusion of gases takes place more than mixing and the lighter gases like hydrogen and helium are more abundant.

Water vapour in the atmosphere is a source for all forms of precipitation and is an important absorber and emitter of infrared radiation. Carbon dioxide, besides being involved in the process of photosynthesis, is also an important absorber and emitter of infrared radiation. Ozone layer, present at a height range of 10 to 50 km (average height of 35 km) above the earth, is an effective absorber of ultraviolet radiation from the sun.

Air also holds lots of tiny particles called aerosols. Some aerosols like dust and pollen grains are picked up naturally when the wind blows through dust generating

areas and flowering plants. Large amounts of CO_2 the most important contributor to human-caused global warming are also produced when cars and power plants burn coal, oil, and gasoline. Such polluted atmospheric condition is harmful to humans and animals.

However carbon dioxide in the air is both good and bad: for humans and animals it is harmful while for plants it is useful during the day time as a raw material to produce carbohydrate in a process called photosynthesis. In this process, plants give off oxygen which is beneficial to all animals and humans. However during the night in a reverse chemical process the plants give out carbon dioxide absorbing oxygen. The cycle of plant-carbon-dioxide-oxygen during the day time and plant-oxygen-carbon-dioxide during night time is very crucial for all living beings on earth. Plants with green leaves are the link between inorganic chemicals such as CO_2 and H_2O and organic chemical like $C_6H_{12}O_6$ (carbohydrate) trapping or releasing about 686 kilo-calories of energy from the sunlight during day time. During the night plants do absorb oxygen and give out carbon-dioxide. Fig 3 provides a diagrammatic representation of the photosynthesis (Light reaction) and respiration (Dark reaction).

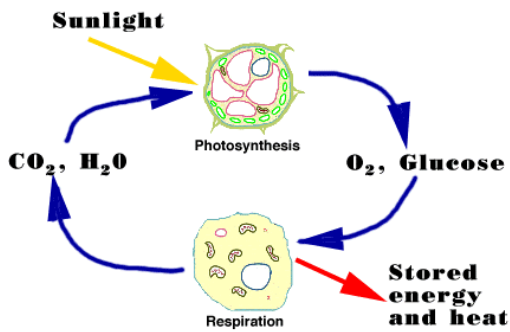


Fig 3 Photosynthesis and respiration cycle in plants

Relative humidity is another phenomenon we experience of the air. It is the amount of moisture present in the air held at a particular temperature. Humidity is usually measured in percentages, so the highest level of relative humidity is estimated to be 100 per cent just before the rain. Humidity in the air is measured with an instrument called a psychrometer. Greater the forest cover more will be the humidity and greater will be the chance of rainfall and water recycling in the nature.

Though air seems be light, a column of air can exert pressure known as air pressure which varies inversely with the height. Air pressure at sea level is considered maximum and as the height increases the pressure decreases proportionately. Hence when we are on the top of a mountain there is less air pushing on you and the pressure is low. Pressure measuring instrument is called a barometer.

To the earth air acts like a protective layer insulating from getting too cold or too hot. The ozone layer in the atmosphere also protects us from too much of harmful component of the sunlight like ultra violet (UV) rays. Air in the atmosphere can also protect us from meteoroids. When meteoroids contact our atmosphere, they rub against the air creating friction generating heat energy which burns them up before they reach the Earth.

Air volume also can harbor living organisms like microbes. We are familiar with diseases spreading through air like Covid-19 virus; these tiny microbial organisms are called bio-aerosols. They can travel long distances through the air—via wind, rain, or even by a sneeze of a human or animal.

Air is in constant movement at varying speed from almost zero to 407 km per hour the maximum recorded in the history. Air movement can be in any direction and

can even become cyclic called cyclones causing loss of human life and properties. But wind is also a propagator of seeds and spores of plants and microbes. Wind erosion is a major problem in the desert areas carrying sand particles kilometers away from their original location.

Types of weather

Following are the most common weather conditions

1. Sunny: It means basically having plenty of sunshine throughout the day. Sunny days in winter or in cool climate are very pleasant whereas in summer days it is unbearable. Hence the day temperature may be varying with a wider range from minus fifty to plus fifty in various parts of the earth. Wherever there is sunshine of eight or more hours, solar panels may be installed to generate electricity. At present solar power generation could cover a quarter of global electricity needs and by mid-century it is expected to become the second largest power generation source after wind. Global capacity must reach 18 times current levels, or more than 8000 giga-watts by 2050. But the greatest beneficiary and converter of solar energy into chemical energy on earth is the plant kingdom. The green pigments called chlorophyll in plant leaves are able to convert water and atmospheric carbon dioxide into carbohydrate using the sun light energy though only about 1-2 percent of the solar energy is used by them; the rest of the sunlight is reflected back into the atmosphere. This captured solar energy is converted into many forms of carbohydrates (food items for humans and animals), fuel wood, fodder items, fibers and natural medicinal and spices items by various plants along with release of oxygen essential for all animal and human lives. But at night the opposite reaction takes place absorbing oxygen and releasing carbon dioxide. These reactions that take place in the plants are called light

reaction during the day time and dark reaction during the night as given in the chemical formulae in Fig 4.

Day time: $6CO_2 + 6H_2O + \text{Sunlight (684kcal)} \rightarrow C_6H_{12}O_6 + 6O_2$ **(1)**

Night time: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy (684kcal)}$ **(2)**

Fig 4. Photosynthesis (1) Light reaction and (2) Dark reaction

Humans seldom realize that it is the sun energy that is stored up in various forms of food items both for humans and animals and how great a role is played by the sun light and the atmosphere through which the sunlight is filtered through. It is the same sunlight that coverts water bodies into vapour and rain clouds which when cooled comes down as rain which supplies water to all living beings. Thus it is the atmosphere that screens the sunlight off the harmful rays and also condenses the rain clouds into showers of rain. It is the sun's energy that is stored up in the plant parts in the form of various types of carbohydrates like food, edible oils, fuel, fodder, organic fertilizers, fiber and construction fabricates. Certain number of sunny days is necessary for most plants to grow and develop to the stage of flowering and fruiting.

2. Windy

Certain areas on earth have windy weather blowing constantly. Netherland is known for the constant blowing of the wind; similarly most of the seashore areas are marked by constant blowing of the wind. Certain hilly areas have constant wind blowing. The constant wind is caused by

the continuous variations in the atmospheric pressure or vice a versa; but why do we get these differences? It's due to the rising and sinking of certain amount of air volume in the atmosphere. Where air is rising we can observe the low pressure on the earth's surface, and where it's sinking we will observe higher pressure. Air movements helps in maintaining pressure, temperature, oxygen and carbon dioxide ratio within certain range beneficial to all living beings. Wind energy is very beneficial to mankind. However too much of wind is also very dangerous and destructive.

3. Stormy

When the wind is too much and accompanied with rain we call it a stormy weather signifying a number of climatic factors. They are produced by the large and thick clouds that can generate *cumulonimbus* (menace looking multi-layered cloud formation), extending high up into the sky in a towering cloud plumes causing storms, with a wind speed of about 30-32 kms/hour accompanied with heavy rainfall and/or hails stones. Such a storm regardless of its intensity can be a dangerous to people, animals and trees. Storms occur everywhere but are rare at polar region. In the temperate regions, they happen especially during late spring, summer, and early autumn but are more frequent in mountains and tropical areas. A prolonged stormy weather can result in landslides, heavy floods and turbulent sea.

4. Tornadoes and Cyclones/ Hurricanes/ Typhoons

a. Tornado

Tornadoes are rotating air columns spinning at a very high speed with a funnel shaped cloud reaching down to the ground and moving around on the surface in a narrow irregular path; it is mostly happening on land areas and is

formed when a funnel-like column of cold air sinks down from a higher area of warm air or warm air rises up with whirls causing high speed circulation of winds; both have relatively a smaller diameter. They happen mostly under the spell of thunderstorms, which are a specific kind of a column of spinning cloud with flat shaped formation at the base and top (*cumulonimbus*). Tornadoes act as a sort of "natural vacuum cleaner", sucking in and projecting out everything it can take on its path. Tornados are measured by FUGITA and TORRO scales developed by the Tornado and Storm Research Organization (TORRO) in the United Kingdom. FUGITA was a scale developed to asses a tornado on the basis of the damage caused by it, while TORRO was developed later to measure the wind speed which is considered a better method of assessing a tornado. Perhaps from the environmental point of view measuring both the wind speed and the extent of damage would be a better method. Tornado is relatively small compared to cyclones, but the damage may be extensive. Fig 5 show an enhanced FUGITA scale to estimate the damage caused by Tornado and in Fig 6 is given the TORRO scale to measure the wind speed of the tornado. As given in Fig 5, FUGITA has six categories (F0 to F5) of damages such as light damage, moderate damage, considerable damage, severe damage, devastating damage and incredible damage, whereas in TORRO in Fig 6, scale there are thirteen classifications (from zero to twelve) with their nomenclatures given against each row. There are many variations of these two scales and more descriptions of the tornados available in the internet sources for people who want to study about Tornados more.

Enhanced Fujita Scale (EF-Scale)	
EF0	65 to 85 MPH
EF1	86 to 110 MPH
EF2	111 to 135 MPH
EF3	136 to 165 MPH
EF4	166 to 200 MPH
EF5	201+ MPH

Click on the buttons to see the effects of the wind, then return to this chart.

Beaufort No.	Speed (M.P.H)	Description of Wind Force
0	Under 1	Calm
1	1 - 3	Light air
2	4 - 7	Light breeze
3	8 - 12	Gentle breeze
4	13 - 18	Moderate breeze
5	19 - 24	Fresh breeze
6	25 - 31	Strong breeze
7	32 - 38	Near gale
8	39 - 46	Gale
9	47 - 54	Strong gale
10	55 - 63	Storm
11	64 - 72	Violent storm
12	73 and over	Hurricane

Quiz

Fig 5 FUGITA Scale and Fig 6 TORRO Scale

Tornadoes gobble up dust and debris that make them visible during the day and, depending on the materials swallowed, make them light grey, grey, or even brown. The night tornadoes are normally invisible making them much more dangerous and threatening but lightning can reveal their existence and position. Tornadoes make also a lot of sounds, especially the strongest ones, which can help to identify them with little to no visibility. Most tornadoes do not produce winds faster than 200 km/h, although these winds can already kill an unprotected person and destroy a house.

The 1999 Bridge Creek tornado, in Oklahoma, US, was one of the strongest recorded tornado with a speed of 512 km/h, or 40% of the speed of sound. However, the largest recorded tornado was 2013 El Reno tornado, again in Oklahoma had a diameter of 4.2 km and was estimated to have had a wind speed of 541 km/h (44% of the speed of sound). Both of these tornadoes destroyed everything in their paths, although the El Reno tornado, fortunately, didn't cross urbanized areas of Oklahoma.

Since tornadoes are extremely dangerous, it is important to be on the lookout for one if supercells (a large slow-moving volume of updraught and downdraught which causes violent thunderstorms, heavy hail, and tornadoes (whirlwind) are predicted for your area. Tornadoes can occur pretty much everywhere in the world, but they mostly appear within mild climates.

b. Cyclones/ Hurricanes/ Typhoons (CHT)

They are the different names for the same phenomenon and it is purely an oceanic occurrence. A cyclone consists of a low-pressure area with high speed wind spiraling round and round. The pressure and speed at a point in a fluid or air

will be in inverse relationship (Bernoulli's principle).There is a large scale air mass that circulates around the center of a low atmospheric pressure measured in Beaufort and Suffir-Simpson scale; it can stretch over several hundred kilometers. Fig 7 provides a Saffir-Simpson Hurricane Wind Scale Value Chart. A cyclone is a huge and powerful spiraling storm originating in the sea but later spanning out into wider direction of land or sea causing heavy stormy rain causing huge damage to people and property. High-speed winds go around the centre violently and are often accompanied by heavy rains. They usually have large diameters. Fig 8 provides a cross sectional view of a sample Cyclones/Hurricanes/Typhoons (CHT). From this cross sectional view one can easily make out the mushroom like structure and the directions of the air movements of the spiraling cyclone/hurricane/typhoon. At the innermost we can notice the eye of the storm itself spiraling in anticlockwise direction; due to the law pressure created below the mushroom umbrella the moist air from the ocean rises up getting mixed up with the cool air at the top; eventually the umbrella like structure spreads across the sky far and wide and finally the energy of cyclones/hurricanes/typhoons get spread out and dissipated. Depending on the size of cyclone it might have traveled hundreds or thousands of kilometers and caused irreparable damage to people and properties. So far, in spite of the tremendous advance in science and technology, there is no way to prevent a cyclone or to mitigate their effects when it occurs.

Saffir-Simpson Hurricane Wind Scale			
Category	Wind Speeds		
	Miles (mph)	Kilometers (km/h)	Knots (kn)
FIVE	≥ 157 mph	≥ 252 km/h	≥ 137 kn
FOUR	130 to 156 mph	209 to 251 km/h	113 to 136 kn
THREE	111 to 129 mph	178 to 208 km/h	96 to 112 kn
TWO	96 to 110 mph	154-177 km/h	83 to 95 kn
ONE	74 to 95 mph	119 to 153 km/h	64 to 72 kn

** This scale only takes wind speed into consideration.*
** Only used for hurricanes that form in the Atlantic Ocean & Northern Pacific Ocean.*
** In 2012, the NHC expand the windspeed for category 4 by 1 mph in both directions.*

Fig 7 Saffir-Simpson Hurricane Wind Scale

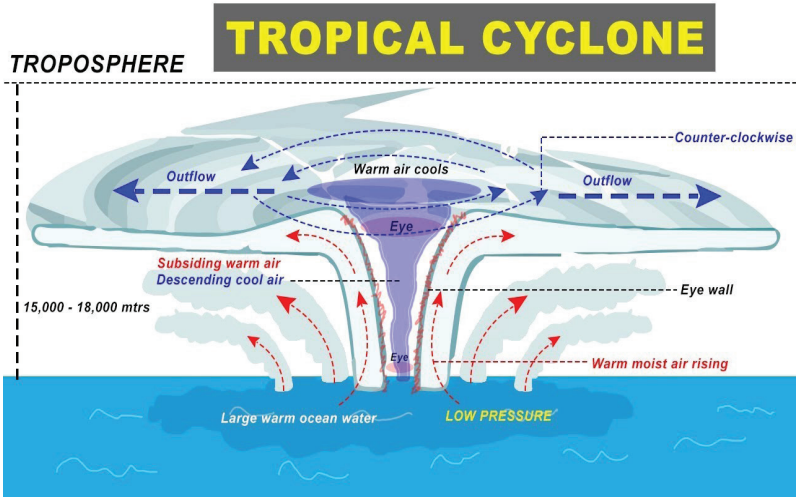


Fig 8 Cross section of a Cyclone/Hurricane/Typhoon (CHT)

Then how and why the different names like Cyclones, Hurricanes or Typhoons occur? It seems the different names are assigned to the same phenomena depending on the

geographic and demographic variations in the population and their linguistic culture. This is well depicted in Fig 9 of the world map in which are marked the areas where various names of the same like Cyclones, Hurricanes or Typhoons are marked and also the areas on the globe where CHTs are likely to occur. The term hurricane is used by North Americans for storms arising both in the Northern Atlantic and Pacific regions in the northern hemisphere whereas the term typhoon is used for storms arising in the Japan-China side of the Pacific ocean, whereas Cyclone is used for the same phenomenon by the countries in the Indian ocean like Australia and the adjacent countries. India and nearby countries also use the term cyclone for the same phenomena. Otherwise one could say that hurricanes and typhoons occur in the tropical storm areas of Northern hemisphere and cyclones occur in the tropical storm areas of the southern hemisphere.

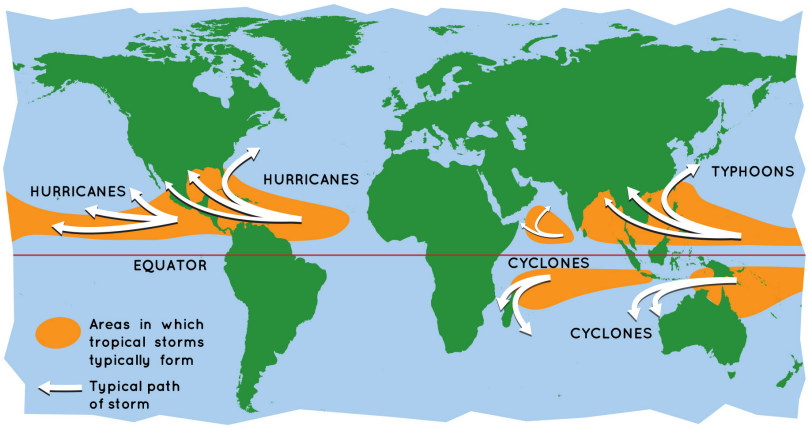


Fig 9 Geographically different names for the same thing

Following are the distinguishing characteristics between cyclones/hurricanes/typhoons and tornados.

1) Cyclones/hurricanes/typhoons is a large-scale air

mass that circulates around a center of low atmospheric pressure whereas tornado is a rotating column of air accompanied by a funnel-shaped cloud that moves around in a narrow path over the land.

2) Cyclones/hurricanes/typhoons is purely oceanic phenomena whereas tornado is primarily over-land phenomenon.

3) Cyclones/hurricanes/typhoons is measured by Beaufort scale and Saffir-Simpson scale whereas Tornado is measured by Fujita enhanced Fujita and TORRO scale.

4) Cyclones/hurricanes/typhoons strecth over several hundred miles whereas tornado is relatively small but the damage may be extensive.

4. Thunder snows

It is a kind of thunderstorms of intense snowing in temperate and arctic regions but much milder than the real thunderstorms occurring in the tropical regions. In this the snows of different types fall instead of rain or hail stones; thunder snows tend to be very weak and short compared to common thunderstorms though heavy snowing may occur for long duration which can pile up on rooftops. It may or may not be accompanied with lightning and thunder. Poor visibility may cause vehicle accidents. The winds of the thunder snows can cause property damage, extremely low wind chills, and frostbite.

5. Fog

Fog is like visible aerosol like water spray of tiny particles or ice crystals suspended in the air at or near the Earth's surface. Fog can be considered a type of low-lying layers of fog like a cloud. It is much influenced by nearby water bodies, forest density, height and topography of the

terrain and wind conditions. Fog may mean a spread of cloud at ground level raising the humidity to the maximum decreasing considerably the visibility up to 20 meters of less. When the fog condition provides a visibility more than 1 km we name it as mist. Fogs can happen anywhere, even in deserts, but happen more frequently in cold, humid climates. Depending on the time of the day, fog can appear in various shades of grey, varying from light grey at solar noon, to dark grey at the sunset.

Fogs make biking and driving particularly dangerous, especially if the visibility is less than 100 meters. In some countries, speed limits are reduced when fog occurs. For instance, in some countries the speed limit is reduced to 50 km/h or less if a fog decreases visibility to less than 50 meters. In some countries, meteorological warnings are emitted if a fog is predicted to take place. In India, fog in the winter season cause undue delays of flights, trains or even vehicles on the road.

7. Sandstorms

Sandstorms are large surges of sand and dust raised by strong desert winds giving an appearance of a dull brown hazy screen in the horizon. Though sandstorms are not lethal, yet if the quantity of fine sand particles in the air is beyond a certain limit, breathing or any outdoor activity becomes very difficult and even dangerous. Sandstorms usually happen in hot deserts, but exceptional weather patterns can allow sandstorms to sweep over non-desertic regions.

8. Weather Phenomena

Atmospheric system is one of the most dynamic components of the earth's eco-system effecting out such changes that are very difficult to predict or foresee.

Changes are happening daily or even hourly in the weather patterns and events that are part of the atmosphere. While these patterns and events are necessary for our planet to continue to be life-sustaining, they can also cause substantial damage and sometimes cost billions of dollars in rescue and restoration efforts.

Weather phenomena can be defined as natural events that occur as a result of a combination of several dynamic factors in the atmosphere such as various levels of heights, pressure, temperature, air density and circulation, ionization, humidity, sun light and heat variations, impact of human animal interventions, the spherical shape of the earth, the spin of the earth on its axis, its slant of 23.5 degree on its axis, earth's rotation around the sun, the gravitational influence of other planets, the circular movement of the solar system around the Milky way our galaxy, and the rotation of Milky way itself, etc. Above all the atmospheric system itself is subjected to the Coriolis Effect.

The **Coriolis Effect** is named after a French mathematician and physicist Gaspard-Gustave de Coriolis. It simply means that any flying or moving things in the atmosphere, or currents of air traveling long distances around the Earth appear to **move in a curvature** as opposed to a straight line. It is an effect whereby an object of any mass moving in a rotating system experiences a force (the *Coriolis force*) acting perpendicular to the direction of motion and to the axis of rotation. As a result winds, oceanic currents, and drift ice are deflected rightward causing an anti-clockwise rotation in the Northern Hemisphere and leftward causing clockwise movement in the Southern Hemisphere. Hence the Cyclones/ Hurricanes/ Typhoons etc. rotate anticlockwise in the northern hemisphere and

clockwise in the southern hemisphere. At the equator the Coriolis force is zero but increases as one move to the North Pole or South Pole.

Earth's rotation is primarily responsible to the Coriolis Effect. Earth's rotation at the Equator is faster than that of at the poles. Earth is wider at the Equator, so to make a rotation in one 24-hour period, equatorial regions race nearly 1,600 kilometers per hour; whereas, near the poles the speed of the rotation is as low as 0.00008 kilometers per hour.

When warm air arises near the Equator it will flow toward the poles: in the Northern Hemisphere, these warm air currents are deflected to the right (east) as they move northward but at the same time the currents descend downwards toward the ground at about 30° north latitude. As the current descends, it gradually moves from the northeast to the north and to the northwest and back toward the Equator. These consistently circulating patterns of these air masses in anticlockwise are known as trade winds. In the same way in the Southern Hemisphere, these warm air currents are deflected to the left (east) as they move southward, but at the same time the currents descend downwards toward the ground at about 30° south latitude. As the current descends, it gradually moves from the southeast to the south, then to southwest and back toward the Equator. These continuously circulating patterns of air masses in clockwise direction are also known as trade winds. Both directions of rotations and movements are shown in Fig 10.

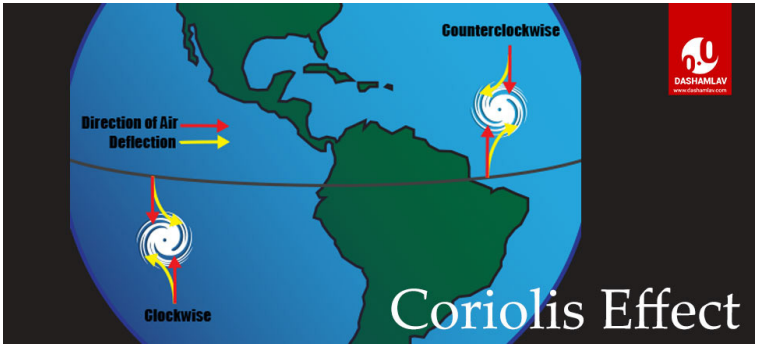


Fig 10 Clockwise and Counter clockwise movements of the cyclones

Impact on Human Activity

The weather impacting fast-moving objects, such as airplanes and rockets, is influenced by the Coriolis Effect. The directions of prevailing winds are largely determined by the Coriolis Effect, and pilots must take that into account when charting flight paths over long distances. Military snipers sometimes have to consider the Coriolis Effect although the trajectory of bullets is too short to be greatly impacted by Earth's rotation, sniper targeting is so precise that a deflection of several centimeters could injure innocent people or damage civilian infrastructure.

The Coriolis Effect on Other Planets

The Earth rotates fairly slowly, compared to other known planets. The slow rotation of Earth means the Coriolis Effect is not strong enough to be seen at slow speeds over short distances, such as the draining of water in a bathtub. Jupiter, on the other hand, has the fastest rotation in the solar system. On Jupiter, the Coriolis Effect actually transforms north-south winds into east-west winds, some traveling more than 610 kilometers per hour. The divisions between winds that blow mostly to the east and those that blow

mostly to the west create clear horizontal divisions, called belts, among the planet's clouds. The boundaries between these fast-moving belts are incredibly active storm regions. The 180-year-old Great Red Spot on Jupiter is perhaps the most famous of these storms.

The Coriolis Effect in our daily life

We cannot observe the Coriolis Effect by watching a toilet flush or a swimming pool drain. The movement of fluids in these basins is dependent on manufacturer's design (toilet) or outside forces such as a strong breeze or movement of swimmers (pool). However, one can observe the Coriolis Effect if you and some friends sit on a rotating merry-go-round and throw a ball back and forth. When the merry-go-round is not rotating, throwing the ball back-and-forth is simple and straightforward. But when the merry-go-round is rotating, a ball thrown will not make to your friend sitting across; you will have to throw the ball ahead of the movement of the merry-go-round whether it is rotating clockwise or anti-clockwise. Actually, the ball is traveling in a straight line. You and your friends on the merry-go-round are moving out of the path of the ball while it is in the air. Another friend, standing on the ground near the merry-go-round, will be able to notice this. Storms in the north swing counter-clockwise while storms in the south swing clockwise. Though the Coriolis force is useful in mathematical equations, there is actually no physical force involved. Instead, it is just the ground moving at a different speed than an object in the air.

Polar Power

The Coriolis force is maximum at the poles but nil at the Equator. Cyclones need the Coriolis force in order to circulate. For this reasons, hurricanes almost never occur

in equatorial regions, and never cross the Equator itself; it happens in the southern or/and northern hemispheres.

Other Weather Phenomena

1. Blizzard

Blizzard is defined as the storm of/with snowfall resulting very poor visibility. Blizzards are real threat to those who travel or are in the open air.

2. Clouds

Clouds are the base for most other weather phenomena taking place like rain, snow, lightning, hail and thunderstorms; all these originate from clouds. Hence some details about clouds will be useful to environmentalists. The list of different types of clouds is given as follows; however snapshots of these clouds would make it easy for the readers to distinguish between them for which the readers are advised to refer the internet sources.

High Clouds (occur at 16,500-45,000 feet height)

Cirrus clouds *are delicate, feathery clouds that are made up of mostly of ice crystals. Their wispy shape comes from wind currents which twist and spread the ice crystals into strands.*

Cirrostratus clouds *are thin, white clouds that cover the whole sky like a veil. These clouds are most commonly seen in the winter, and can cause the appearance of a halo around the sun or the moon.*

Cirrocumulus clouds *are thin, sometimes patchy, sheet-like clouds. Sometimes they look like they're full of ripples or are made of small grains.*

These clouds could be a sign of an approaching hurricane!

Mid-level Clouds (occur at 6,500-23,000 feet height)

Altocumulus clouds *have several patchy white or gray layers, and seem to be made up of many small rows of fluffy ripples. They are lower than cirrus clouds, but still quite high. They are made of liquid water, but they don't often produce rain.*

Altostratus clouds *are gray or blue-gray mid-level clouds composed of ice crystals and water droplets. The clouds usually cover the entire sky.*

Nimbostratus clouds *are dark, gray clouds that seem to fade into falling rain or snow. They are so thick that they often blot out the sunlight.*

Low Clouds (occur at less than 6,500 feet)

Cumulus clouds *look like fluffy, white cotton balls in the sky. They are beautiful in sunsets, and their varying sizes and shapes can make them fun to observe!*

Stratus clouds *often look like thin, white sheets covering the whole sky. Since they are so thin, they seldom produce much rain or snow. Sometimes, in the mountains or hills, these clouds appear to be fog.*

Cumulonimbus clouds *grow on hot days when warm, wet air rises very high into the sky. From far away, they look like huge mountains or towers.*

Stratocumulus clouds *are patchy gray or white clouds that often have a dark honeycomb-like appearance.*

Special Clouds

Contrails *are made by high-flying jet airplanes. They are still clouds, though, because they are made of water droplets condensed from the water vapor in the exhaust of the jet engines.*

Mammatus clouds *are actually altocumulus, cirrus, cumulonimbus, or other types of clouds that have these*

pouch-like shapes hanging out of the bottom. Pouches are created when cold air within the cloud sinks down toward the Earth.

Orographic clouds *get their shape from mountains or hills that force the air to move over or around them. They can also be formed by sea breezes and often appear as lines where two air masses meet.*

Lenticular clouds *are shaped like lenses or almonds or... flying saucers! They may get their shape from hilly terrain or just the way the air is rising over flat terrain.*

3. Dust

Dusts are phenomena that occur when one area on the ground heats up more than surrounding areas. This hotter area then heats the air above it, creating a column of circulating air, which picks up dust and other debris from the ground.

4. Fog

Fog is a fascinating event that occurs when the air temperature cools and condenses water molecules from a gas to a liquid forming a very thick a very thick fog.

5. Frost

Frost is a beautiful and majestic phenomenon that is usually one of the first signals that winter is on its way. It requires three things in order to form higher levels of water vapor in the air, low wind speeds, and low temperatures overnight.

6. Haboob

Haboobs are giant walls of dust that form in desert areas in front of a thunderstorm cell. They are created by downward thrusts of cold air inside the storm cell, which

blows sand and dust outward. These events can be seen in places such as the Sahara Desert and southwestern United States.

7. Hailstorm

Forming at high altitudes in massive cumulonimbus clouds (a dense, towering vertical *cloud*, forming from water vapor carried by powerful upward air currents), hail can grow as big as 8 inches or more and fall at velocities over 160 kilometers per hour. It has the potential to cause damage to crops, roof tops of various materials like glass, plastic, tin or aluminum sheets.

8. Heat Wave

While heat wave is less spectacular and less visible than other weather phenomena, heat waves can be considered among the most dangerous to humans and animals. Temperatures remain above normal for days or weeks. India, Pakistan, Afghanistan, Iran, countries in the tropical Africa are countries that experience heat waves.

9. Cyclones/Hurricanes/Typhoons

With wind speeds exceeding 150 miles per hour and diameters over 350 miles, cyclones/hurricanes/typhoons are among the most devastating weather phenomena.

10. Lightning

A voltage capable of becoming as high as 1 billion volts, lightning is spectacularly brilliant and dangerous at the same time. Lightning is a discharge of electricity. A single stroke of lightning can heat the air around it to 30,000°C. This extreme heating causes the air to expand explosively fast creating a shock wave that turns into a booming sound wave known as thunder.

11. Rain

Rain is a necessary requisite for the survival of most forms of life on Earth. But in large quantities it can quickly become a disaster. The phenomenon of rain is a very complex factor to study but can be summarized as, "Raindrops fall to Earth when clouds become saturated with moisture droplets. Millions of droplets bump into each other as they are formed in a cloud. When a small water droplet bumps into a bigger one, it condenses or combines, with the larger one and fall to the earth due to the gravitational force".

12. Rainbow

Rainbows are as much atmospheric optical phenomena as they can occur only under certain atmospheric conditions. A number of amazing physical processes should occur in order for us to see one. Ultimately we can say that, that part of the moist curvy atmosphere through which sunlight passes through acts like a prism diffracting the sunlight into seven colours.

13. Snow

Though snow is an interesting phenomenon liked by most people can be beautiful, calming, peaceful but dangerously damaging depending on various conditions. It accumulates in a place at a much faster rate than rain.

14. Thunderstorm

When an unstable atmosphere gives way to cumulonimbus clouds, and large electrical imbalances begin to form in the atmosphere a thunderstorm is likely to occur. With potential for hail, high winds and tornadoes thunderstorm is one of nature's most dynamic events.

15. Tornado

Tornadoes require several conditions to develop, including a wind speed that increases with altitude and then a super cell (a large slow-moving area of updraught and downdraught which causes violent thunderstorms, heavy hail, and tornadoes). Once formed, the wind speeds have the potential to exceed 200 miles per hour.

16. Air pollution

Air pollution is measured with the Air Quality Index, or AQI. The lower the AQI, cleaner will be the air quality. When the AQI is over 100 in the area where you live and work it will about the same as breathing in exhaust from a car all day. Things that cause poor air quality are forest fires and high vehicular traffic in the cities. If the AQI is higher than 100 one should not spend too much time outside.

Global warming and climate change

Global warming is the long-term upward change in the temperature of earth's climate system observed since the pre-industrial period (between 1850 and 1900) due to production of too much of green house gasses like carbon dioxide, methane, nitrous oxide and some artificial chemicals such as chlorofluorocarbons (CFCs). Burning of fossil fuels like coal, petrol or diesel also increases heat-trapping greenhouse gasses in earth's atmosphere. Global warming is measured as the average increase in the temperature of the earth's surface. Disappearing glaciers, early melting of snows, severe droughts, forest fires, poor plant and forest growth, severe water scarcity, eye and nose irritation in people, increased dust and carbon particles in the atmosphere, drying up of water sources, rise of sea level submerging many of the law lying areas of the world etc. are the main effect of global warming. Emergence of new pests

on forests, farms and in the cities happens. Frequency and intensity of heat waves will be more accompanied with heavy downpours, and increased flooding which can damage or destroy all types of agricultural, animal husbandry and fisheries systems and enterprises. Global warming disrupts or destroys habitats of many forms of precious marine life. Global warming increases incidence of allergies, asthma, and infectious diseases; increased production of pollen grains and fine dust particles are conditions favorable to pathogens and mosquitoes. Economically poor and marginalized people are hit maximum by global warming even though their contribution to global warming may be nil or insignificant.

Weather reporting

Weather forecasting is an applied science to predict the conditions of the atmosphere for a given time and place. Informally people have been predicting the weather for millennia with their instinctive and intuitive sense and formally since the beginning of 19th century. In the modern world climate reporting has become a matter of great importance and need or even a necessity in all spheres of life: economic, social, cultural, agricultural, tourism etc. These days all businesses depend on weather conditions. Hence weather warnings are important to protect life and property. All modes of travel and transport especially the air and water travel is very much depending on the weather conditions. Most of the military operations are planned and executed according to the weather conditions of each day. And for ordinary people weather forecasts are very useful to take precautions in their day to day life. Perhaps the farmers are the ones who are depending on the weather maximum. Another field which is affected maximum is the road transport and tourism.

For instance, warm climate may force some species to migrate to higher latitudes or higher elevations where temperatures are more conducive to their survival. Similarly in winter many species including humans migrate to less cold or warmer places. The main factors that combine to influence weather are solar radiation, the earth's tilt on its axis, orbital distance from the sun, temperature, air pressure and the moisture content in the atmosphere. Many are the types of weather conditions such as sunny, cloudy, semi dark, foggy, drizling, rainy, snowy, hail stormy, cold, freezing, icy, sleeting, stormy, lightening, thunder, windy, tornado, rainbow, clear sky, hot, warm, dusty, stormy etc.

Almost all the countries have meteorological departments to monitor the weather conditions in their country. However the weather changes are not restricted to one or two countries alone; often it is a world or continental or regional phenomena. Hence several channels report world and local level weather conditions several times a day. The common instruments of measure weather changes are anemometer, wind vane, pressure sensor, thermometer, hygrometer, and rain gauge. The weather measures are formatted in a special format and transmit to World Meteorological Organization (WMO) to help modeling of the weather forecast.

In the modern times weather forecasting is done through satellites having super computers and going around the earth several times during the day and night to detect even the slightest atmospheric changes and transmit them to super computers kept at various earth stations. At present we are able to predict weather conditions several days in advance so that each country can take appropriate precautionary measures.

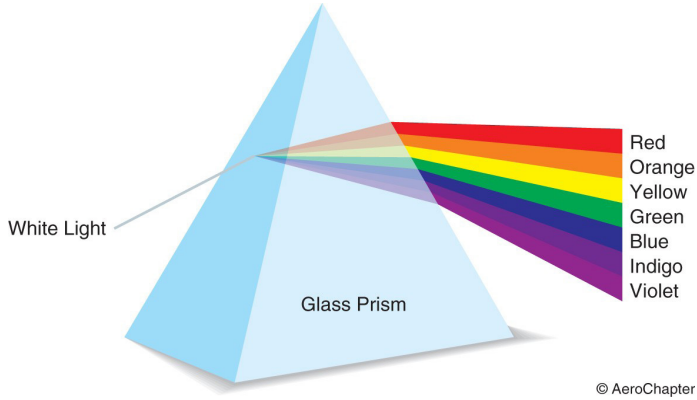
LIGHT AND HEAT

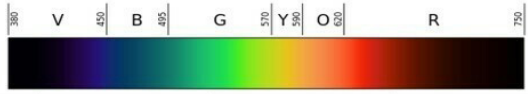
Light and heat are essential ecological components supporting and sustaining any form of life systems on the earth. Sun is the natural source of heat and light energy for every living being on the earth. They enhance many physico-chemical and biological actions and reactions on earth. The light energy is used by almost all the chlorophyll containing plant organisms to convert it into starch (Fig 4) which is a chemical energy essential for carrying out all functions in the living organisms. All life forms use chemical energy to carry out all their life functions. Heat energy is required to maintain conducive living conditions. There can be variations in the intensity of light and heat from the optimum range to extreme variations at the lower and higher ranges. Both the heat and light energy from the sun pass through the space which is a huge atmospheric volume to reach the earth. There is a continuum as well as a series of fluctuations in the intensity of light, heat, wind speed, pressure and humidity in the atmosphere that envelope the earth. Both light and heat are two forms of the same energy. Something can get very hot but still not emitting visible light; living creatures also emit heat without light, as do many other chemical reactions. Heat is a form of kinetic energy contained in the random motion of the particles of a material whereas, light is a form of electromagnetic energy. As with other forms of energy, heat energy can be transformed into light energy and vice versa. Lights occur at different frequency levels: higher the frequency longer will be the wave length and higher will be the energy; lower the frequency shorter will be the wave length and lower will be the energy.

Sunlight is a portion of the electromagnetic radiation given off by the Sun. It is composed of subatomic particles

called photons, a type of elementary particle having no electric charge or rest mass but has one unit of spin; they are field particles that are thought to be the carriers of the electromagnetic field. It is also considered as a quantum of the electromagnetic field including radiation such as light and radio waves. Photons are massless, so they always move at the speed of light in vacuum, 299,792,458 meters per second. Light can be produced by several ways such as incandescence, electric discharge, phosphorescence, fluorescence, chemiluminescence, bioluminescence, triboluminescence etc.

There are seven basic properties of light such as 1) Reflection of light, 2) Refraction of light, 3) Diffraction of light, 4) Interference of light, 5) Polarization of light, 6) Dispersion of light and 7) Scattering of light. All these seven properties of light can be studied in detail to get an in-depth understanding of the mysteries in the behavior of light. **Light** is composed of particles called photons, and the **matter** is composed of particles called electrons, protons, neutrons. It's only when the mass of a particle gets small enough that its wavelike properties show up. Sun light consists of mainly seven colours having varying wavelengths, frequency and photon energy as shown in Fig 11 and 12. There is a range of variations in the wave lengths between two successive colours. For example ultra-violet rays have a shorter wavelength than the violet rays. Similarly infra-red wave has a higher wavelength (800 nm) than the red colour (620-750) in the spectrum. Infrared waves, or infrared light, are part of the electromagnetic spectrum.





Color	Wavelength	Frequency	Photon energy
violet	380–450 nm	668–789 THz	2.75–3.26 eV
blue	450–495 nm	606–668 THz	2.50–2.75 eV
green	495–570 nm	526–606 THz	2.17–2.50 eV
yellow	570–590 nm	508–526 THz	2.10–2.17 eV
orange	590–620 nm	484–508 THz	2.00–2.10 eV
red	620–750 nm	400–484 THz	1.65–2.00 eV

Fig 11 & 12 showing diffraction and various other properties

Each colour of light exerts environmental impact at varying intensity either positively or negatively. For example rupture in the ozone layer in the atmosphere allows ultra-violet rays which are harmful to human beings while infra-red rays are beneficial to humans in several ways. What we get on earth is the scattered part of the sunlight filtered through earth's atmosphere.

Sun is mostly a huge ball of hydrogen gas and there is a

tremendous amount of continuous process of fusion of hydrogen atoms is taking place creating the Helium. Hence the estimated composition of sun at any given time is 75% hydrogen and 25% helium. As a result of this continuous fusion tremendous amount of photons in the form of light energy are released from the surface of the sun. Sunlight takes about 8.3 minutes to reach Earth which is about 150 million kilometers away from the surface of the Sun. Huge amount of heat energy is produced at the center of sun which is estimated to be around 15 million degree centigrade and the temperature at the periphery is about 5600 degree Celsius. According to NASA, lightning is four times hotter than the surface of the sun and the air around a stroke of lightning can peak up to 50,000 degrees Fahrenheit (27760 C). A photon starting at the center of the sun and changing direction every time it encounters a charged particle would take between 10,000 and 1,70,000 years to get to the surface of the sun showing how big is the sun which holds 99.8 per cent of the weight of the solar system. Only after that the light can travel to the earth and other planets.

Sunlight is a key factor in photosynthesis, a process used by plants and other autotrophic organisms to convert sun's light energy into many forms of chemical energy called carbohydrates to fuel all the activities of any organism. There are two ways for the humans to use sunlight to make useful forms of energy. One is to use photovoltaic panels to make electricity. The other, simpler approach is to convert sunlight to heat for such things as warming a building, making hot water, cooking, or producing "steam" that can power an electrical generator. Heat and light are different but they are two forms of energy. Heat is a form of kinetic energy contained in the random motion of the particles of a material. Light is a form of electromagnetic energy. As with other forms of energy, heat energy can be transformed into light energy and vice versa.

The Earth absorbs most of the sun energy reaching its surface, a small fraction is reflected. In total approximately 70% of incoming radiation is absorbed by the atmosphere and the Earth's

surface while around 30% is reflected back to space and does not heat the surface.

Lightning and Thunder

Lightening is a naturally occurring electrostatic discharge during which two electrically charged regions both in the atmosphere or with one on the ground, temporarily equalize themselves, causing the instantaneous release of energy as much as one gigajoule (one billion joule) of energy. This discharge may produce a wide range of electromagnetic radiation, from heat created by the rapid movement of electrons, to brilliant flashes of visible light in the form of black-body radiation. Lightning causes thunder, a sound from the shock wave which develops as gases in the vicinity of the discharge experience a sudden increase in pressure. Lightning occurs commonly during thunderstorms as well as other types of energetic weather systems, but volcanic lightning can also occur during volcanic eruptions.

The three main kinds of lightning are distinguished by where they occur: either inside a single thundercloud, between two different clouds, or between a cloud and the ground. Many other observational variants are recognized, including "heat lightning", which can be seen from a great distance but not heard; dry lightning, which can cause forest fires; and ball lightning, which is rarely observed.

Thunder is the sound caused by lightning. Depending upon the distance from and nature of the lightning, it can range from a long, low rumble to a sudden, loud crack. The sudden increase in temperature and hence pressure caused by the lightning produces rapid expansion of the air in the path of a lightning bolt. In turn, this expansion of air creates a sonic shock wave, often referred to as a "thunderclap" or "peal of thunder". The study of thunder is known as *brontology*. Changes in climate can result in impacts to local air quality. ... Emissions of pollutants into the air can result in changes to the climate. Ozone in the

atmosphere warms the climate, while different components of particulate matter (PM) can have either warming or cooling effects on the climate.2

Concluding Remark

The atmosphere and atmospheric changes taking place on a daily or hourly basis is so different and so intricate that it is very difficult to predict the possible weather conditions on a day. Most of the changes taking place on the land in the sea are also influenced by or even triggered by changes in the atmosphere and in the soil-water-air relationships. The surface of the earth is subjected to so many variations; equal or more are the types of variations taking place in the atmosphere which influence all living and nonliving beings on earth.

Chapter-7

Soil in the Ecosystem

Introduction

Soil is the substratum for all living and nonliving components of the earth-eco-system. It not only supports the plant life in general but also determines the productivity of crops for food, fuel, fiber, fabricates for construction, fertilizing organic manures, pharmaceutical plant parts and products. That everything living has its existential base on soil is so well expressed in the saying "One foot soil decides the destiny of mankind". Hence the study of soil is necessary for every environmentalist to have a minimum skill to manage the soils of his immediate environment in a sustainable way.

The Indian population is increasing at a rapid pace and at present we have more than 1300 million people to be fed and adding every year 20 to 22 million more heads per year to feed, cloth, house and to educate. To meet the food grain requirement for the ever increasing population we can have two options: bringing more land under cultivation or producing more from the same piece of land. In a country like ours which is so densely populated and where 43% of the total geographical area (against 11% of international average) is already under cultivation, the first option seems to hold no promise. The second option of increasing the productivity per unit area seems to be viable though the productivity of the Indian soil is miserably low because the tradition-bound Indian farmer follows mostly their age old

labour intensive farming techniques. Anything done on land by way of agriculture, animal husbandry or forestry affects the environment drastically and mostly negatively. We are already over-cultivating our land area in India.

As already mentioned in other chapters every country is supposed to have at least 70% of its land area under perennial forests. The rest 30% of land area is only available for agriculture including animal husbandry and for all other non-agricultural usages. If allotted equally both for agricultural and nonagricultural usages both sectors would get 15% each of the rest of the land area. The land area cannot be increased on the surface of the earth; hence only judicious use of the available agricultural land area is the only option. Any land use pattern directly affect the environment positively or negatively; our role is to guide all agricultural and animal husbandry use of land into an environment friendly way. Therefore every environmentalist should have enough knowledge about soil management.

The soil is a thin layer of the earth's crust made up of disintegrated and decomposed rocks and complex inorganic compounds, organic matter, water, air and living organisms like bacteria, algae, fungi, insects, worms etc. The inorganic material forms the bulk of the soil volume both volumetrically and gravimetrically. The top cultivated or cultivable soil is completely different from the bottom layers of soil as we can notice when we cut vertically profile of a meter or two deep as shown in Fig 1. The different layers of soil are synthesized in profiles (differentiating soil layers or horizons) and its physical, chemical and biological properties differ completely though they may be formed from the same material. Soils also differ among themselves in factors under which they have formed. Thus some soils are red, some are black, some are deep and some are shallow, some are coarse and some are fine textured and so on. From the factors given above, it is clear that there might be some

portions of earth's crust where there is no soil. For example places covered with ice, rocky areas etc, may not have any soil.

If a well developed and unploughed soil is cut vertically one can find different layers having different widths, different colours, differently sized particle arranged in different manner and even greatly different amounts of components present in them. These layers are called horizons (mainly O,A,E,B,C,R as shown in Fig 1); and the group of horizons together is called soil profile. However from the agriculture point of view the term mature soil is referred only to the top layer of soil. In other words one can say that a mature top soil contains all the four components (1. mineral matter 2. organic matter 3. soil air and 4. soil water) more or less in the proportion mentioned above and in a thoroughly mixed form signifying the O and A horizons as shown in Fig.1. Such a top soil posses several properties.

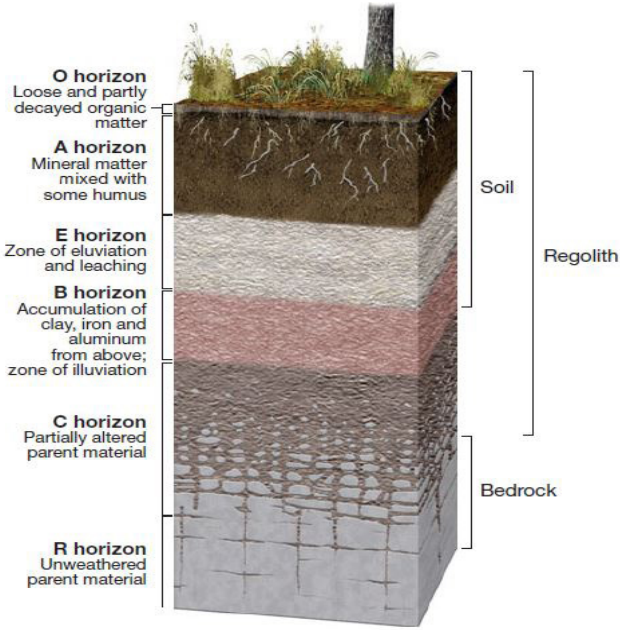


Fig 1 Soil profile and its horizons

FORMATION OF SOIL

As we all know, the earth like all other planets was a gaseous portion separated from the gaseous sun. It took billions of years to cool down to molten lava type of matter which again took billions of years to cool down to rocks. Again it took billions of years to form a centimeter thick soil from the degraded rocks. It is estimated that it takes 100-500 years to form one cm thick layer of soil. Soil formation is the result of interactions among five different factors, viz. (1) parent material, (2) climate (3) vegetation, (4) topography or relief and (5) time.

1. Parent material: Rocks are the chief source of parent material over which soils develop. These are the consolidated forms of various chemical compound called minerals. There are three kinds of rocks found in nature (a) igneous rocks, (b) sedimentary rocks, and (c) metamorphic rocks.

a. Igneous rocks: Those solid masses which originate by cooling and solidification of molten magma are called igneous rocks. These are the toughest among all the rocks and are mainly composed of two minerals, namely, quartz and feldspars. Some examples of igneous rocks found in India are granite, diorite, basalt and gabra just to mention a few.

b. Sedimentary rocks: when igneous rocks are exposed to atmosphere, they are subjected to sunlight and heat, cold and hot wind at different speed, force of falling rain drops and gushing streams, moving glaciers, etc. They are then slowly worn out slowly and steadily into small particles which are carried away by agents like wind and water and deposited at different places. Over a long period these deposits get solidified due to the pressure exercised by further depositions above them and sedimentary rocks are formed. Examples of these rocks are limestone, sandstone, and shale.

c. Metamorphic rocks: When the igneous and sedimentary rocks are naturally subjected further to an intense heat or pressure or both, then their whole chemical structure is transformed. These types of rocks are called metamorphic rocks. Some examples are marble (from limestone), quartzite (from sandstone), gneiss (from granite) and slate (from shale).

2. Climate: Climate is a combination of temperature, rainfall or humidity and wind speed. These climatic factors act upon the parent materials (rocks) to disintegrate them. Fluctuations in temperature loosen the rock formations; striking actions of raindrops and blowing of high speed winds slowly and invisibly erode the rocks producing sandy soil particles.

3. Vegetation: The type of vegetation dependents on climate. Vegetation is necessary for the formation of organic matter component in the soil. Expanding roots of growing vegetation exert physical pressure on rocks and make the rocks vulnerable to disintegration. Decomposition of vegetational by-products produces many acids which accelerate the process of soil formation.

4. Topography or relief: Topography (relief) influences the pace of soil development. On steep lands, most of the soil-forming materials are continuously flushed down to streams and rivers during the rainy season and are carried to faraway places and ultimately to the sea. Thus on steep lands we find soils of very shallow depth while in the plains and low lying areas deep soils are found.

5. Time: If the soil forming processes have been active for long time of thousands of years and above, deep and mature soils are formed. Those soils which have not undergone disintegration process for a sufficiently long time are called young soils. They are shallow, stony and immature soils.

6. Components of a Mature Soil: A soil cannot be called mature if it does not provide favorable conditions for plant growth. For a soil to be productive, it must have the following four basic components: 1. mineral matter (45%), 2. organic matter (5%), 3. soil air (25%) and 4. soil water (25%). Mineral matter forms the bulky part of the solid components of the soil. Mineral matter of the soil has its origin from rocks. Rocks are subjected to a degenerative or erosive process in the nature called weathering. Due to weathering massive rocks are disintegrated, deconsolidated and finally converted into numerous very small particles of mineral matter. When these are held together there will always be some space between them. These spaces are occupied by air and water which are termed as soil air and soil water components of the soil. If some spores or other entities of biological origin happen to be part of this aggregate state of soil, they can germinate and grow. In the course of time, some primitive lower plants may also grow on this soil which, when die, result into a very important component of soil called organic matter or humus. The amounts of these four components are highly variable (especially air and water) which depends upon climate conditions under which they are formed and remain.

PROPERTIES OF SOIL

The properties of soil can be studied under three heads: physical properties, chemical properties and biological properties.

A. Physical properties: Physical properties are superficial properties of soil which can be easily observed or felt. They have nothing to do with the chemical nature of the soil. They can be discussed as follows.

1. Soil texture: Soil texture refers to the solid fractions

of the soil consisting of particles of various sizes. The relative size of soil particles is termed as soil texture or soil separates. As shown in Table 1, based on size of soil particles there are three kinds of soil textures as given in table 1.

Table1 Size of the soil separates

Sl. No	Soil separates	Size of particles
1.	Sand	0.02 mm or more
2	Silt	0.02-0.002 mm
3	Clay	0.002 mm or less

Based on the presence of the amount of sand, silt and clay, soils are classified texturally into twelve classes as given in Table 2. Soils containing all the textural separates in desirable amounts are called loam soils which are more suitable for agricultural purposes.

Table 2 Soil textural classes

Sl. No.	Soil Class or Textural Name	Range of relative percentage of soil separates		
		Sand	Silt	Clay
1	Sand	85-100	0-15	0-10
2	Loamy soil	70-90	0-30	0-15
3	Sandy loam	43-80	0-50	0-20
4	Loam	23-52	28-50	7-27
5	Silt loam	0-50	50-88	0-27
6	Silt	0-20	8-10	0-12
7	Sandy clay loam	45-80	0-28	20-35
8	Clay loam	20-45	15-53	27-40
9	Silty clay loam	0-20	40-73	27-40
10	Sandy clay	45-68	0-20	40-60
11	Silty clay	0-20	40-60	40-60
12	Clay	0-45	0-40	40-100

Sand particles are big in size and attract very little water

and plant nutrients. Thus sandy soils are not productive agriculturally. Clay particles being small in size, have much affinity to water and nutrients and, thus are productive. Silt has intermediate particle size and a good mix of the three types soil separates are better for agricultural production.

2. Soil structure: Most soils contain all the three textural particles mentioned above. These particles are arranged in a definite structural manner. The manner they are arranged in, is called soil structure. The soil structures are mainly classified as (a) single grain, (b) granular, (c) blocky, (d) prismatic/columnar, (e) platy and (f) massive as shown in Fig 2 given as follows.

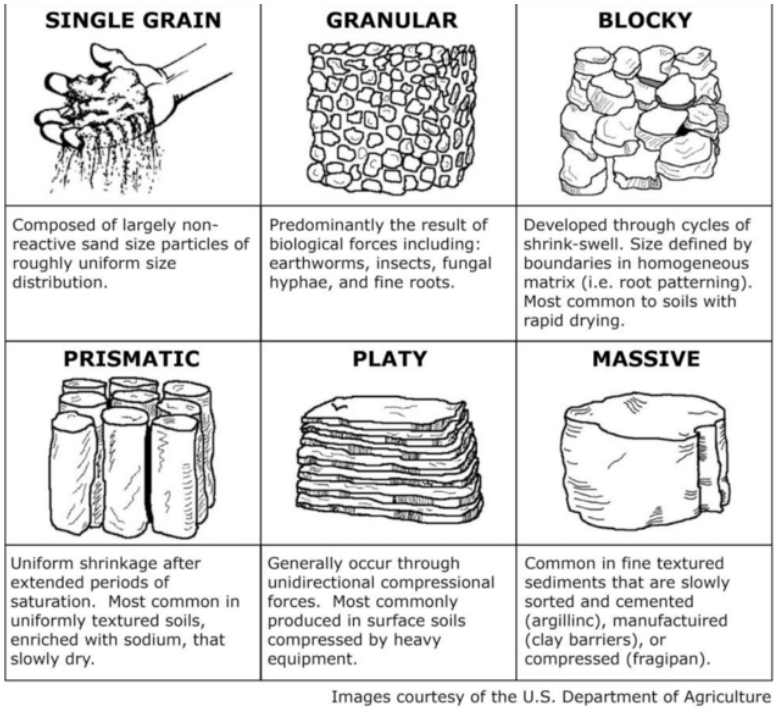


Fig 2: Different soil structures

a. Single grain: a heap of pure sand is an example

single grain soil; each grain of sand is independent; they do not stick together.

b. Granular: In granular structure, particles adhere to one another and form a grain like structure ranging 3 to 6 mm in diameter. This is the best soil structure which provides all the suitable conditions for crop growth.

c. Blocky: In blocky structure, particles stick together to form a solid block having sharp edges,

d. Prismatic/Columnar: In prismatic/columnar structure, particles coalesce together to form a vertically raised prismatic of columnar structure. Tops of the columns are rounded while that of prismatic is hexagonal.

e. Platy: In platy structure particles arrange themselves in a flat plate like structure and plates are arranged over one another

f. Massive: Massive structure means the condition of a soil layer in which the layer appears as a coherent solid mass not separated into parts of any kind and are found deep within the soil.

3. Soil density: Density of the soil means mass of soil per unit volume of soil contains is called soil density. It is expressed as g/cm^3. Density of the soil is expressed in two forms: (a) Particle density and (b) Bulk density.

a. Particle density: Particle density is the density of soil without pore space (i.e. only solids):

$$\text{Particle density} = \frac{\text{Weight of solids}}{\text{Volume of solids}} = \text{weight of the soil without pore spaces}$$

b. Bulk density: Bulk density is the density of soil along

with air. This is practically, more important than particle density.

$$\text{Bulk density} = \frac{\text{Weight of soil with pore spaces}}{\text{Volume of soil}}$$

4. Soil porosity: The spaces occupied by air and water between particles in a given volume of soil are called pore spaces. Generally the particles of a normal soil encompass as much volume of pore spaces as the volume of particles themselves (i.e. 50%). Their percentage of soil volume occupied by pore spaces or inter-particle spaces is called porosity of the soil.

5. Permeability of soil: Permeability refers to the ability of the soil to allow downward movement of water more influenced by the gravitational force. It depends upon the amount and size of pore spaces: greater the pore space faster will be the movement of the water. Seepage refers to the movement of water in any direction including upwards due to the influence of the adhesive and cohesive forces.

6. Soil colour: Variation in the colour of soils is due to the presence of different compounds. Humus and other organic substances impart black colour to the soil. Iron compounds are responsible for brown, red and yellow colours of the soil. Iron oxides in combination with organic substances impart brown colour which is the most common soil colour. Silica, line and other inorganic compounds give light and grey tinges to the soil.

7. Soil temperature: Temperature governs the activities of soil organisms which are of vital importance to soil and plants. Soil gets heat mainly from three sources; solar radiation, deeper layers of earth and decaying organic

residues. Temperature of the soil at a time depends upon weather, colour and slope of soil, vegetation etc. Temperature of surface soil is subjected to a wide fluctuation, whereas it remains more or less constant in deep soil.

8. Soil plasticity, cohesion and adhesion: When a moist soil is twisted a little, it does not break apart, rather it assumes the shape which you give by twisting. This ability of the soil to tolerate external pressure is its moist state is termed as soil plasticity. The property of plasticity in the soil due to two forces always acting in a moist soil: cohesion and adhesion. **Cohesion** is the attractive force acting between molecules (finest form of any matter) of the same substance; for example, one water molecule is attracted towards another water molecule. **Adhesion** is responsible for attraction between the molecules of two different substances (e.g. attraction between water molecules and soil particles). These forces keep the soil and water together.

B. Chemical properties of soils

1. Inorganic matter: As discussed earlier, rocks are broken into small sized minerals due to the process of weathering. Minerals are the compounds of many elements like calcium, magnesium, silicon, aluminum, iron, potassium etc. They are called inorganic matter of soil because they do not originate from any living thing like plant or animal or microorganisms. The amount of these minerals in a soil depends upon the type of parent material and climatic conditions under which they are formed.

2. Organic matter: Organic matter is that part of the soil which is derived from living things. Plants, animals, organisms, once alive, die and add to the pool of organic matter in the soil. In normal soils it accounts for about 5% of the soil volume. It ranges widely from 1% in sandy soils

to 20% in organic soils. In soils which have developed under intense vegetation (especially high rainfall, low temperature zones), it may go as high as 90%. When plants and animals die, their dead remains are subjected to decomposition. As a result of decomposition, a number of different organic compounds are formed from the original residues. In the course of decomposition, the original materials are converted into dark coloured organic substances, called humus. Sometimes, living organisms add sufficient amount of organic matter in soil in the form of metabolic wastes.

When plant and animal by-products come to the soil, they will have to decay or decompose. When they decay, they release as many nutrients as they had absorbed from the soil or their body consists of. These nutrients are absorbed by growing plants. This important process of decomposition is brought about by microorganisms living in the soil such as algae, fungi bacteria and actinomycetes.

3. Colloidal property: Soil contains the particles of greatly variable size. To understand the colloids in a better way, we can do an experiment. Take a handful of soil in a glass container. Pour enough water into the container, shake the container and leave it undisturbed for a few minutes. We can note the following:

a. Some particles are so small that they almost dissolve in the water changing its colour.

b. Some are big and heavy that they settle down at the bottom; and

c. Some are so small sized that they neither dissolve in water nor settle down in the bottom of container; they remain suspended in the water. Such particles are called colloids. Colloids are soil particles remain suspended in water.

There are two types of colloids: 1. Soil colloids and 2. Humus colloids: Soil colloids hold a small number of bases and hence the soil is of low base status and is less fertile, whereas Humus colloids have high soil fertility due their higher number of base charges. To these charges, charged atomic particles of various chemical elements called ions get attached and which are absorbed by the root hairs of plants in the presence of moisture. Acid ions have the ability to replace the nutrient bases sticking to the surfaces of the soil. The plant nutrients dissolved in the soil are in the form of ions: cations or anions which are charged positively and negatively charged respectively. These charged nature of ions and colloids form the mutual exchange phases for plant nutrients supported by the ubiquitous osmotic pressure difference between the cells in the root hairs and the thin layer of water molecules.

The size of colloids is below 0.002 mm in diameter. The presence of colloids in the soil is essential. It is this fraction of soil which retains water and plant nutrients in the soil. Plant nutrients are absorbed on the surface of colloids and supplied to the plants in times of need. Colloids thus reduce the leaching loss of nutrients. The size of decomposed organic matter (humus) and some inorganic mineral matter (clay) are such that they can be called colloids. The presence of humus and clay in sufficient amounts is essential for a soil to be fertile.

4. Soil reaction: Soil reaction is assessed by measuring the amount of acidity or alkalinity of the soil. The scale to measure soil reaction (nature) is called pH. Soil with pH 7 is neutral in reaction and the best for most of the crops. Soil with pH more than 7 is called saline and alkaline and one with less than 7 is called acidic (Table 3). Due to some ecological imbalances, concentration of salts on the

surface soil goes high and pH of the soil also goes up; thus soils become alkaline/saline. If the sodium (an element) is in excess amounts, soils are called alkaline. If salts are leached out due to excessive rainfall, pH goes down and soils become acidic. Neither saline/alkaline nor acidic soils are suitable to most of the crops.

Table 3 Soil groups based on pH

Sl. No.	pH	Classification of soil
1	Less than 7	Acidic soil
2	At 7	Neutral soil
3	More than 7	Alkaline soil

C. Biological properties of soil: The top soil is an ideal medium for organisms to live. A vast number of organisms live in the soil. They belong to both animal and plant kingdom. Some organisms are big enough to be seen by the naked eye. Some are so minute that they can be seen only through a microscope. For convenience, soil organisms are grouped in two categories depending upon their size. (i) macro-organisms and (ii) micro-organisms.

1. Macro-organisms: those organisms which can be seen by the naked or unaided eyes are called macro-organisms. They include mice, insects, millipedes, snails, mites, earthworms, moles, spiders, centipedes, algae plants, etc. The main work of macro-organisms is to make the big sized organic residues into small pieces by gnawing, chewing, eating, digesting and excreting. They move in subsoil and provide better aeration to soil. When they die and disintegrate into the soil, they contribute to the organic matter pool of the soil.

2. Micro-organisms: Those organisms which can be seen only through a microscope are called micro-organisms. They include minute algae, fungi, bacteria, actinomycetes, etc. These micro-organisms are of tremendous importance to soil as they carry out decomposition of fresh organic (plant and animal) residues added to the soil. They exist in the top soil in astoundingly huge numbers as shown in table 4 given as follows.

Table 4 Population of organisms in the soil

Sl. No	Type of Organism	Number
1	Bacteria	10^9/gm soil
2	Actinomycetes	10^7/gm soil
3	Fungi	10^6/ gm soil
4	Protozoa	10^6/ gm soil
5	Algae	10^5/ gm soil
6	Earthworms	10^6/ acre furrow slice

SOIL AND PLANT GROWTH

The soil plays a vital role in the growth and development of a plant. The functions of the soil with reference to plant growth are briefly discussed as follows.

1. Mechanical support: The soil serves as a mechanical support for crops to stand erect. Thus it is a medium in which the growing plants find their anchorage through their root system. Plants are enabled to maintain the firm position of roots, thereby helping the parts above ground to perform their respective functions normally. When plants are grown without soil (hydroponics) mechanical support to plants is required to be given by means of stakes or a network of wires. Hydroponics is mostly confined to research purposes. However a number of vegetables are grown by hydroponics

for commercial purpose. But for large scale crop production the importance of soil in providing mechanical anchorage to plants cannot be avoided.

2. Storage of plant nutrients: The soil serves as the natural store-house of the plant food (nutrients). Many soils, without any manuering or addition of fertilizers can yield moderately good crops for a pretty long time.

3. Providing basic requirements for seed germination: For any seed to germinate, the presence of three factors names, air, temperature and moisture in appropriate amounts is indispensable. The soil provides all these factors in quite rational amounts to allow seed germination. Further growth of seedlings also gets favorable conditions in soil.

4. Chemical changes: The soil serves as the seat of many chemical reactions in the presence of air and water. The total effect of these reactions sets free plant foods (nutrients) and neutralizes harmful products.

5. Microbial activities: the soil is a seat too of teeming microorganisms which together with available nutrients engage in making the soil richer and healthier to the spread and functioning of the root system.

SOIL AND WATER CONSERVATION

We have seen that the top soil is the storehouse of water and nutrients for all types of plants for human and animal and for other purposes. Erosion is the physical loss of the top soil or upper most layer of the soil which is the most important part of the soil, sustaining all the life activities of plant and animal kingdom. Loss of top layer of soil means loss of soil fertility for all practical purposes. Under natural conditions it takes about 800 to 1000 years to generate one inch thick layer of top soil. Sometimes we can lose

this precious natural resource by not protecting it against erosion.

As a natural habitat of all the living beings, soil is a basic resource for all our agricultural activities. Fortunately, our country is blessed with a variety of soils and climate. Therefore, soils can sustain a variety of vegetation and produce handsome amount of food, fiber and wood crops. It is great thing to know that all the crops in the world can be grown in India due to its variety of climatic conditions. But today, when the pressure of human activities has built up beyond the carrying capacity of the soil, overuse and misuse of this precious resource has set in. Carrying capacity of a soil originally refers to the number of a cattle heads that a unit of land area (per acre or hectare) can support for long time; now it also refers to the number of people a unit area can support in life. A hectare of very fertile soil can support more people and cattle while a barren soil may not support any at all.

Slope of the land and intensity and extensiveness of forest cover are two most important factors that determine the soil stability and soil fertility. All the slopping lands above 15-20 per cent should never be put to seasonal cultivation and those below should be terraced and soil conservation structures like leveling and plotting should be done before any seasonal cropping is done. Slopes from 15 to 33.3 per cent should never be subjected to seasonal or biennial cropping but only to perennial crops orchards or planted forests with adequate soil and water conservation structures and all the lands above 33.3% slope should be kept under perennial forests planted or natural along with sufficient soil and water conservations structures.

Over large areas in our country, forest cover has been destroyed. Demand for fuel woods and manufacturing

woods are increasing day by day. Need is felt to bring more and more land under cultivation. Shifting cultivation is still going on. Pressure on arable land is mounting with rapid pace. All these factors tend to accelerate soil erosion.

A. Soil Erosion in India

In India, there is very little area free from soil erosion. It is estimated that out of 305.9 million hectares of surveyed land, 145 million hectares is in need of conservation measures which is 3 million hectares more than the total arable land of the country (Table 5).

Table 5: Problem of conservation of land and water in India

Sl. No	Particulars	Estimated area in million hectares	
		Total area (ha)	Soil conservation problem area (ha)
1	Forest	61.170	20
2	Cultivated wasteland	17.362	15
3	Pastures & grazing lands	14.809	14
4	Land under miscellaneous crops	4.218	1
5	Fallow lands: i. Old fallows	9.168	8
	ii. Current fallows	11.132	7
6	Net area under cultivation	137.900	80
7	Other land uses: buildings, roads, railways, cities, towns, aerodromes etc.	50.188	–
	Total	305.947	145

According to a study conducted by the Central Soil and Water Conservation Research and Training Institute, Dehradun, nearly 6000 million tones of soil is being eroded annually from our country, of which 29% is being permanently lost to the sea, 10% is deposited in reservoirs as silt and the remaining 61% is displaced from one location to another. The study further warns that the annual average loss of top soil is approximately 16 tones/ha which is four times more than the permissible limit of 4 tones/ha. In soil erosion always the top soil is eroded year after year and often permanently too. Along with this soil, a vast amount of plant nutrients is lost. It is estimated that the country is losing 30-50 million tons of food grains worth top soil every year by not protecting the cropping land against erosion. The eroded soil particles carry away with them attached nutrients from fields into streams. Often the finer portion of the soil is removed which is rich in organic matter and soil fertility. Various estimates show that about 2.5 million tones of nitrogen (N), 3.8 million tones of phosphorus (P_20_5) and 2.6 million tones of potash (K_2O) are lost every year from Indian soils due to erosion. This loss exceeds the total indigenous production of nutrients in terms of 4.1 million tons of fertilizers in the year 1981-82.

B. Factors Affecting Soil Erosion

Soil erosion is a process in which soil particles are detached and transported away from their original places to the sites where they are of little agricultural value. The process is carried out mainly by two agents; the air and the water. There are certain factors which affect the extent and intensity of erosion of a soil. These can be briefly discussed as under.

1. Climate

Rainfall, temperature and wind are the main climatic factors causing soil erosion. If the amount of rain water is in excess to the absorption capacity of the soil, movement of water on soil surface starts (run-oft). Run-off water contains soil particles, the amount depending upon the intensity of rainfall. If the torrential rainfall is accompanied with blowing wind the severity of erosion is increased tremendously by the strong hitting action of raindrops, detach the soil particles from their original locations. Small particles go down and choke the pores of surface soil thereby reducing the permeability of soil to the water. The particles on the upper most soil surface are drained away along with run-off water. An extensive rainfall of long duration may not cause excessive erosion. Similarly, an intensive short duration rainfall may not produce sufficient runoff to cause erosion. When both amount and intensity of soil erosion factors are high in a given storm runoff, erosion will be serious.

On a broad climatic basis, temperature affects the type and amount of vegetative cover that exists. The same amount of precipitation may be more effective in producing vegetative cover in cool climates than in warm climate. The soils of warm climatic zones contain less amount of organic matter as it is decomposed rapidly due to high temperature. Therefore, the soils of these regions are more susceptible to erosion. On the other hand, light temperature reduces the viscosity of water, thus increasing its infiltration or percolation into the soil and facilitating microbial activities.

2. Topography

Slopping lands are the most vulnerable to soil erosion. The intensity of erosion of a soil depends upon the degree or percentage of the slope and on the length of the slope. More

the degree and the length of the slope greater will be the soil erosion. Investigations have shown that if the land slope is increased by two times, the velocity of water flowing over it will be doubled. When the velocity is doubled, erosion capacity of the water is increased by 4 times, the amount of soil particles of a given size that can be carried is increased approximately by 32 times and the size of a soil particles that can be transported by pushing or rolling is increased by about 64 times. If the slope of the land is against the direction of wind, wind erosion will be high. Thus the cumulative effect on soil erosion increases in geometrical proportion.

C. Vegetation

Vegetation has direct impact on the amount of soil erosion: greater the vegetation lesser will be the soil erosion. Vegetation prevents the soil erosion in the following ways.

1. Widespread foliage of the plants intercepts the falling raindrop. The force, with which raindrops hit the soil, is greatly reduced. Some portion of the rainfall is held by foliage and evaporated from there to the atmosphere.

2. If the rainfall is heavy enough to produce run-off on soil surface, growing vegetation acts as physical barrier to moving water. The speed of the water movement on soil surface is reduced. The water movement is slow enough to allow the soil particles suspended in it to settle down on the soil surface. Loss of soil by erosion is thereby greatly reduced. Soil absorbs greater amount of rain water.

3. Roots of crops, especially fibrous root system of grasses, keep the soil particles bound together by their knitting and binding action and prevent the soil erosion. After harvesting the roots are left in the soil to decay. The decayed roots leave air spaces in the soil which facilitate

downward movement of water into the soil. Decayed product of roots called 'humus' also helps in binding the soil particles together. A cubic meter of soil allowing growth of vegetation may contain several kilometers long root fibers.

4. Soils having well grown vegetation provide suitable shelter to a lot of useful organisms. Soils under thick forest cover allow prolific growth of earthworms, beetles and other insects. These organisms improve soil aeration and permeability. When they die, they provide organic matter and a binding capacity to the soil and help in the development of good soil structure resistant to erosion.

5. Vegetation also contributes to the water absorbing capacity of the soil by transpiring water. If the water absorption capacity of the soil is increased, run-off of the water on the soil surface is decreased and, consequently, loss of soil along with run-off water is also reduced.

6. Standing vegetation creates physical hindrance to blowing air and flowing water and thus saves the soil from wind and water erosion.

D. Soil properties

Erosion of a soil also depends upon the soil properties. Soils which are quite permeable to water, leave little water for runoff and are fairly resistant to erosion. In compact soils, runoff rate is very high and surface soil is easily washed off. Soils rich in organic manure are resistant to beating action of raindrops or blowing. Very fine clay particles of soils can be easily transported by moving water but it is difficult to detach them from the soil blocks. Big sized sand particles are difficult to transport by water but severe winds can blow them away and deposit them on fertile sites. Find sandy loams soils are the most desirable from the point of view of erosion resistance. Their particles are not fine enough to

be washed out so easily. They cannot be detached easily by moving water and wind.

TYPES OF SOIL EROSION

Based on the agents causing it, soil erosion is mainly of two kinds: water erosion and wind erosion.

A. Water erosion

Water erosion is caused by the beating action of raindrops and movement of rain water over the soil surface. When the amount of rain water is greater than the water absorption capacity of the soil, water has to move on the soil surface. This process is called 'run-off. Moving water carries the soil particles along with it. Depending on the intensity, water erosion is further classified into the following types. The different kinds of erosions by water like splash, sheet, rill and gully erosion are different kinds of water erosion occurring successively one after the other.

1. Splash erosion

This happens due to the splash of rain drops. If the land is sloppy without any vegetation growing on it falling raindrops detach the soil particles from soil mass. Small particles are suspended in the accumulated rain water. This kind of water is muddy in appearance. When this muddy water moves down in the soil (infiltrates), small particles are deposited in pores occurring between soil particles and the pores are choked. Once if the soil pores are choked, infiltration of water into the soil is stopped or reduced. Run-off sets in and erosion of valuable fertile top soil starts eroding. The detachability and transportability of a soil particle depends upon the size and kind of soil particles and, the size and speed of falling raindrops. The splash erosion may be followed by sheet erosion

2. Sheet erosion

In this kind of erosion, a fairly uniform layer of soil is removed from the surface by the combined action of rainfall and run-off. This is a very dangerous kind of erosion. One can hardly notice it. But a fairly large amount of the most fertile part of soil is lost every year due to sheet erosion. It can rightly be regarded as the "skimming-off of the cream" of the top soil. Sheet erosion is an intensive form of splash erosion. Splash erosion chokes the pores of the soil. If raining continues, a uniform film of fine soil particle is eroded away along with runoff water. This kind of erosion goes unnoticed and therefore, farmers mostly fail to adopt any conservation measures.

3. Rill erosion

Due to continued rainfall and inadequate protective measures, sheet erosion may aggravate to form small channels, scattered throughout the field. These finger sized channels along the slope can be smoothened out by ploughing the field or by carrying out common cultivation practices. This kind of erosion is called rill erosion. Severe form of rill erosion leads to formation of gullies. Rill erosion is, therefore, often regarded as transition stage between sheet erosion and gully erosion.

4. Gully erosion

Gully erosion is the aggravated form of rill erosion. Removal of soil by running water continues and, over the time, deep channels are formed that cannot be smoothened out completely by normal cultivation. Unattended rills get deepened and widened every passing year and land begins to be divided by the network of gullies. Land surface is badly degraded and cultivation is not possible on such land. In rainy season large amount of run-off water moves through

the gullies and carries a vast amount of very fertile soil. After certain years, vegetation especially grass and trees start growing in the gully. Gully reaches a stable gradient, gully walls reach a stable slope and vegetation cover spreads over the gully surface. But gully head continues to progress towards the upper end of the watershed.

According to the size of gullies they are classified into four types. This has been elucidated in table 6.

Table 6: Classification of gullies

Sl.No	Symbol	Description	Specification
1	G1	Very small gullies	Up to 3m deep, bed-width not greater than 18m, side slopes vary.
2	G2	Small gullies	Up to 3m deep, bed-width greater than 18m, sides uniformly sloping between 8-15 per cent
3	G3	Medium gullies	Depth between 3-9m, bed width not less than 18m, sides uniformly sloping between 8-15 per cent
4	G4	Deep and narrow gullies	(a) Depth 3-9m, bed-width less than18m, side slopes varies. (b) Depth greater than9m, bed-width varies, side slopes vary mostly steep or even vertical with intricate and active branched gullies.

5. Stream bank erosion

This kind of erosion is caused by moving water in streams, canals and rivers. Moving water scours away soil from the sides of streams, channels and rivers. This kind of erosion is easily noticeable at the beginning of bends in meandering streams.

B. Wind erosion

Wind erosion is the removal and transportation of soil particles from the surface soil by the action of wind. Striking effect of a fast blowing wind hits directly the soil particles and detaches them from soil surface. These soil particles are blown away by wind and deposited on remote fertile lands. Fertile lands, therefore, lose their agricultural value. Huge deposits of sand called sand dunes, in Rajasthan are the examples of wind erosion.

Wind erosion is a serious problem in arid and semi-arid regions like Rajasthan. In arid zones, rainfall is not enough to permit vegetation. Soils are very deficient in moisture which is necessary to keep the soil particles bound together. Lack of organic matter in the soil also favours wind erosion. Gradual removal of finer particles of clay, silt and humus continues and coarse sand particles are left behind. Sand is highly unproductive as it does not have the capacity to retain water and nutrients. Extensive cultivation, overgrazing of land by cattle and excess tillage (which are still continuing in many places of Rajasthan and other arid zones of the country) expose the land to wind erosion. Farmers harvest their crops along with stubbles. Even the controlled pruning of tree leaves before and during summer season aggravates the problem of wind erosion.

CONTROL OF SOIL EROSION

Although soil erosion cannot be checked completely

yet it can be kept well below the detrimental limits provided suitable conservation measures are adopted. Soil conservation, in a broad sense, means preventing the soil deterioration and erosion. This can be done by using the soil to the most appropriate ways and within its capacity adopting certain vegetational and mechanical measures.

Based on the percentage of slopes soil conservation experts have laid down the concept of "Land Capability Classification" which helps in formulating a long term pattern of soil use as given in table 7.

Table 7: Land capability classification

Sl. No	Class of a land	Percentage of slope in percentage	Adopted land use and suitable soil conservation measures
A	Land suitable for cultivation		
	i. Class I	0-1%	Any crop can be grown with proper crop rotation and green manuering to maintain soil fertility.
	ii. Class II	1-3%	Contour farming, contour strip cropping, cover cropping and contour bunding
	iii. Class III	3-5%	Intensive agronomic measures such as contour cropping, contour strip cropping, cover cropping, terracing and contour bunding should be adopted
	iv. Class IV	5-8%	Contour bunding and terracing. Soil building, erosion-resisting crops can be grown. Intensive agronomic measures should be adopted

B	Land not suitable for cultivation		
	v. Class V	8-12%	Permanent pastures with controlled grazing.
	vi. Class VI	12-18%	Pastures, grasses, forestry, restricted grazing.
	vii. Class VII	18-25%	Forest with restricted felling, contour terracing.
	viii. Class VIII	Greater than 25%	Forests with complete prohibition on grazing and felling of trees.

Table 7 is a broad classification of land use pattern based on the slope of the land because slope is the most determining soil factor that influences greatly the soil erosion. In some literatures the upper limit of land use may be 33.3% slope. However the recommendation is to put all the lands above 20 to 33.3 per cent under perennial forest trees and above 33.3% slope is maintained under perennial forests either natural or planted. Measures adopted against deterioration and rehabilitation of eroded soils are grouped in two broad categories. A. Vegetational or biological measures B. Mechanical or engineering measures.

A. Vegetational measures

Vegetational measures of erosion control can again be divided into three groups, namely, (I) agronomic practices, (2) agrostological methods and (3) dry farming practices.

1. Agronomic practices

According to table 3 lands up to 8 per cent only are suitable for cultivation. All the operations carried out within this slopes all agronomic practices, from land preparation to harvesting of crop in order to have maximum harvest, are done with the aim of retaining the productivity of land

and the practices are referred to as 'conservation farming'. Some important conservation farming methods are briefly discussed here; however at the individual farmer level these methods may be modified or something new may be introduced.

a. Contour farming

In slopes, cultivation should be done on contour lines or across the slopes. A contour line is an imaginary line which connects all the points of land located at equal height. If the land slope is only vertical (horizontal plain being flat) ploughing just across the slope automatically gives the furrow which is exactly on the contour. If the horizontal plain is also zigzag or wavy the furrow on the contour line would be bent or zigzag as to follow a contour line.

The advantage with the contour furrows is that they keep the rain water equally distributed at the same level of height. Water does not accumulate at a particular point of furrow and the chances of the breakage of furrow are reduced to minimum. If furrows are opened with soil turning plough, the soil of the furrow should always be turned towards lower side of the slope. By doing so, a furrow and a ridge follow each other in a sequence. Roots of growing crops strengthen the furrow and ridge both making them resistant to any damage caused by water. Water is also retained along the sides of ridges and soil can get soaked with water to a large extend.

Contour guidelines can be established with the help of a leveling instrument. Tillage should be done parallel to the contour line on both the sides. On large and irregular fields several lines may be required. The spacing between contour lines depends upon the degree of slope. On an average hillside, the first contour should be laid 1 to 1.5

m vertically below the hill top. Subsequent lines should be drawn with the same vertical spacing. Ploughing should be done parallel to contour lines and care is taken that soil is turned towards lower side of the slope. Eventually the land will become more and more leveled and the leveling will be faster in lands up to 2-3 per cent. We can also go for well planned leveling and plotting.

b. Tillage operations

Tillage operations should be carried out very cautiously as they can do both harm and good to a soil. The minimum tillage concept developed recently speaks of only that much tillage which is just enough to pulverize the soil. It emphasizes on the least possible tillage.

If a sandy soil is known to contain fine textured clayey or silty layers in sub-soil, ploughing with soil-turning plough to a depth of 30-45 cm is found useful. But the ploughing must be followed by growing a long duration crop in the beginning; otherwise this practice may prove disastrous. If the soil surface is rich in organic residues, the tillage instrument should be such that it creates maximum roughness, cloddiness, and granulation and prevents loss of organic residues from the top soil. In dry land areas, shallow ploughing gives better results. It removes weeds and enhances moisture retaining capacity of the soil. However, in high rainfall areas deep ploughing should be preferred in order to keep down weeds and preserve greater amount of moisture.

c. Organic manuering

Organic matter is a very important component of the soil which keeps the soil particles clumped together, thereby imparting resistance against erosion. Presence of organic matter is a must for micro-organisms to flourish

in the soil. Micro-organisms secrete some slimy substance which helps in binding together of soil particles. Organic matter particles are 10 to 100 times more efficient in retaining moisture than the fine clay particles of the soil. It is, therefore, highly desirable to keep on optimum level of organic matter in tile soil.

The main source of organic matter in a cultivated soil is organic manure. Use of farmyard manure, compost and green manure should be made in order to keep an optimum level of organic matter in the soil. Addition of anything of plant and animal origin contributes to organic matter of the soil.

d. Crop rotation

Growing of the same kind of crop for years in the same field is a wide spread practice in our country. This practice is not desirable as it depletes certain nutrients and organic matter from the soil more than the others. Addition of a densely grown, deep rooted, erosion resisting crop is necessary. An erosion resisting crop must be grown at least once in two years. All the commonly grown pulse or leguminous crops and grasses are erosion resisting in nature. Their extensively growing dense root system, keeps the soil knitted and bound together. Widely spread foliage of legumes and grasses dissipate the force with which rain drops or wind hit the soil.

In Bihar growing deep rooted legume crop of mung or urd, followed by shallow rooted wheat is found useful. In Vidharbha region of Maharashtra the rotation of cotton, jowar and groundnut has proved useful in controlling soil erosion. Legume crop not only provides organic matter but also enriches the soil with nitrogen which is a very important primary plant nutrient.

The practice of mixed contour cropping is also important from the point of view of soil conservation. In this practice, one main crop is grown with other one or two subsidiary crops in the same field. Growing arhar or urd or mung with millet or maize is a practice of mixed cropping. Maize and millets are main crops and the others are subsidiary crops. In maize + arhar mixed cropping system, maize is harvested and arhar is left in the field for further growth. Besides providing additional income, this practice also reduces soil erosion and helps maintaining soil productivity.

e. Mulching

Mulching is a practice of putting straw, plant residues, leaves or grass on the soil surface to reduce evaporation, erosion and fluctuation in soil temperature. Materials used in mulching, act as physical barriers to movement of water in the soil. Immediate objective of mulching is to reduce loss of moisture from the soil surface by the process of evaporation and protect the soil against the strokes of rain and wind. After decomposition mulching material incorporates organic matter in the soil which enhances erosion resistant power of the soil.

f. Strip cropping

This is a system of cropping in which a soil conserving crop and a soil depleting crop are grown in alternate strips. Strips run perpendicular to the slope of the land (contour line) or to the direction of prevailing wind. The main objective is to prevent soil erosion. For the crops of both the strips and others the agronomic practices are carried out as usual. This is a very practical and effective measure of controlling soil erosion but more feasible in extensive fields located on slopes. Strip cropping is of four types.

i. Contour strip cropping

In this practice, strips are established along contours. An erosion resisting crop or cover crop like legume or grass should be grown in one strip and soil exposing or erosion permitting crop like maize, jowar or bajra should be grown in the following strip and the sequence should be maintained. In every passing season the types of crop in the strips should be interchanged.

ii. Field strip cropping

The strips, in this cropping method may not be exactly on contours. This practice is suitable for uniformly slopping field. The strips should be established across the slope following the contour line.

iii. Wind strip cropping

This practice is mainly meant for avoiding wind erosion. The strips of the crop are established across the direction of wind, regardless of contour.

iv. Buffer strip cropping

In this practice every alternate strip is given to a permanent vegetation of deep rooted grass. The interchange of crops between the strips, every passing season is not possible. This can be practiced in the areas having 5 to 6% slope and also where fodder crops are needed for the farm animals. If the slope is less, one strip of permanent grass can follow every two strips of crop.

From the point of view of soil conservation, some crops are said to be soil depleting and some soil conserving and others soil building. This division of crops is based upon their effect on the land. Rotational growing of these crops is helpful in conserving soil and water.

The crops that cause rapid using up of the organic matter and essential plant nutrients are said to be soil depleting crops. These crops need too much cultivation practices resulting in exposure of soil to erosion. Tall growing grass crops such as jowar, bajra, maize, sugarcane and some others like cotton fall under this category while the crops that can be grown with a minimum of stirring the soil care in varying degrees soil-conserving crops. Non cultivated crops such as alfalfa, clover, grass for hay making or pasture. Conserve the organic matter in the soil. The growing of these crops, therefore, tends to conserve the soil even if some minerals are carried away in the crop that is harvested.

Soil building crops must not only conserve the soil but also build up i.e. make it richer in plant nutrients. Legumes, of course, work best as nitrogen gatherers. They get a large part of them from the air and if they are turned, soil will have that much more nitrogen. Moreover, wide foliage and extensively grown tap roots of legumes markedly reduce soil loss through erosion.

2. Agrostological methods

Agrostological methods involve rotating crops with long duration perennial vegetation or establishing permanent vegetation in the highly eroded lands. The practice of lay farming involves cultivation of agricultural crops in rotation with grasses which is very useful. It improves the fertility of soil and helps in binding of soil particles, thus preventing the soil erosion. Areas prone to heavy soil erosion should necessarily be put under thick cover of grasses. Periodic grazing can also be allowed under favorable climatic condition. The grasses commonly grown in India include *Cynodon dactylon*., *Dactyles glomerata. Eragrostis amabitis. Eragrostis cerbula* etc. Recently, vetiver

grass (*Vetiveria zizinoids)* has been gaining popularity throughout the world thanks to the efforts of World Bank. Vetiver has got an extensively growing fibrous root system. Its roots secrete some fragrant substance, which are rat repellant in nature. Therefore, Vetiver can also be used as a hedge around field boundaries. It is very hardy and can survive even after burning in the field and flooding of the field for many days. Cattle give last preference to vetiver. Vetiver has been found to be very effective in controlling soil erosion. However, in some places of country vetiver experiment has failed miserably due to interference by perfume traders. Farmers, in the beginning, grow vetiver with the sole objective of arresting soil erosion. When the grass is grown up, perfume traders offer fabulous prices as the roots of vetiver (khas-khas) have got perfume value. Farmers dig out and sell the grass. Consequently, huge loss of soil due to erosion takes place. This negative aspect of vetiver growing has to be tackled carefully by growing other types of perennial grasses which are even useful as a fodder. A solution to this problem is to plant grasses similar to vetiver grass such as lemon grass, grasses used for thatching houses and making ropes. Their capacity to control soil erosion is equally good. These grasses can be planted in contour lines in single, double or triple lines or in contour strips in the cultivable slopes at convenient distances depending on the degree of slope. Greater the degree of slopes narrower will be the strips between rows of grass plantation.

Agrostological measures also include plantation of trees in contour lines on the new lands (afforestation) and the lands which have been denuded of forest trees. Plantation of trees in short blocks is known as wind breaks and extensive plantation of trees is called shelter belts. All

these measures are mainly to check the erosion by wind. While establishing shelter belts, care is taken that small sized trees are planted towards windward side and the tall ones are planted towards the leeward side (windward side gets the wind first and leeward side get it after that). A list of trees in this regard is given below (Table 8). Rows of trees are also planted in contour lines dividing the cultivable land in strips. These trees can be interspersed with grasses.

Table 8: Names of some trees recommended for both sides of the wind side and leeward side

On windward side/ wind entering side	On leeward side/ wind leaving side
Leptadenia spartiwn (Dori)	*Acacia senegal* (Kumta/ gumerabia)
Cenchrus ciliaris (Anjan grass)	*Acacia leucophloea* (Safed kikar)
Balanites roxburghi (Hingot hingon)	*Ricinus cummunis* (Castor/arandi) .
Calligonum polygonoids (phog)	*Prosopis spicigera* (Chhonkar/jand/sami)
Saccharwn munja (Munja)	*Prosopis julifera* (Vilayati babul/ algaroba)
Kochia indica (Bur/kauraro)	Parkinsonia sps (Kikar/ babul)

As far as possible, selection of species should be done based on adaptability of species to local soil and climatic conditions and community needs. Along with forestation programme proper care and management practices such as control of forest fire, restricted grazing, checking extensive

felling, formation of reserve forests and extension of forest area, should also be enforced strictly. Grazing is the biggest threat to newly established saplings. If absolutely necessary, system of restricted or rotational grazing can be adopted Proper agronomic practices should be carried out as recommended by agricultural experts of the place.

3. Dry land agriculture

A massive research carried out on dry land agriculture has evolved many viable techniques adaptable in different dry land pockets of the country. The objectives behind all the dry land farming practices are to produce maximum amount of yield within a limited available moisture and protect the soil against erosion. The principle underlying it is to preserve maximum amount of rain water following all the agronomic measures and mechanical methods of erosion control. This moisture is made available to the crop in subsequent growth periods. Purely rain fed, draught resistant varieties are recommended for dryland regions. These are mostly short duration varieties.

B. Mechanical measures

Vegetative means of erosion control are the most feasible and economic measures. However, as the pressure on land is increasing, need is felt to bring even highly eroded and more slopping lands under cultivation. In these lands vegetative measures are not adequate to keep down the erosion. Some mechanical structures are required to be erected before vegetative measures are adopted. Mechanical measures, therefore, serve as supplementary to vegetative measures. The objective behind building mechanical structures is to reduce the degree and length of the slope, reducing run-off and consequently, reducing soil erosion. The following mechanical or engineering methods

have been successfully employed in various parts of the country. The readers must take the help of engineers for the designing and construction of mechanical structures and also for getting clarity of technical terms.

1. Terracing

Terrace is a design or shape given to the slopping land in order to get leveled plots. In the lands of high degree and length of slope, erosion is serious problem. Terraced structure of the field permits little erosion as the degree and length of the slope are considerably reduced even to zero. Terraces act as earthen embankment across the slope which reduce the rate of run-off and thus minimize soil erosion.

In most of the areas, bench terracing is practiced. This method involves making of wide platforms, known as bench terraces, along the contour on the sloppy lands. The width of the terraces and the height between terraces depends on the degree of slope. Bench terracing has made possible the growing of cultivated crops in mountainous regions. In high rainfall areas, channel type of terracing is recommended which permits the controlled removal of excess water. The important feature is to dig a channel for carrying the water. They are also suitable for the areas with low permeability of water. Spreading the water over maximum area in the field is the main concern.

The width and length of the terrace and spacing between the terraces depend upon a number of factors such as degree and length of the slope, proposed cropping patterns, soil management practices, soil characteristics and climatic conditions. While designing the standards of a terrace, care should be taken that a terrace provides adequate capacity for safe disposal of water, creates no hindrance to agronomic operations in the standing crops.

The recommended specifications of a plan for irrigated terraces are given in the table 9.

Table 9 : Specifications for plain terrace

Sl. NO	Slope (%)	Vertical interval-VI (m)	Bench width (m)	Terrace width- HI (m)	Depth of cut (m)	Depth of soil required (m)	Length of bench available per hectare (m)	Area loss due to terracing with 1:5 (percent)
1	7	0.60	8.50	8.60	0.300	0.600	1163	1.4
2	10	0.75	7.50	7.65	0.375	0.675	1307	2.0
3	20	1.00	5.00	5.20	0.500	0.800	1923	3.8
4	30	1.20	4.00	4.24	0.600	0.900	2358	5.6
5	40	1.50	3.75	4.05	0.750	1.000	2469	7.4
6	50	1.80	3.50	3.86	0.900	1.200	2590	9.3

2. Contour bunding

Contour bun ding is a practice of constructing earthen embankments across the slope of the land, following the contours as closely as possible. A series of such earthen bunds divide the areas into strips and act as barriers to the flow of water, thus reducing the amount and velocity of run-off. Cultivation is not done on earthen embankment as it may damage the bonds. Therefore, nearly 5% of the area is lost in bonds and is not available for cultivation. The distance between the contour bunds is kept many meters depending on the soil and climatic conditions and cultivation is carried out in the space left between the bunds. The practice of contour bunding is widely followed in Maharashtra, Gujarat, Tamil Nadu, Karnataka and Andhra Pradesh. Contour bunding is not successful in deep black soils of Maharashtra and Gujarat. The soils of these regions, being very rich in clay, crack in summer. In the following rainy season, water moves through cracks formed in bunds and destroys all the subsequent bunds. In

shallow and medium deep soils having maximum depth of 90 cm, contour bunding has been found to be successful.

While designing the specification for bunds, care should be taken that enough area is submerged during raining so that soil can absorb a large amount of water. For the crops requiring high moisture and on very sloppy lands, spacing between bunds is kept narrower whereas for economizing the construction, wider spacing is kept. Spacing between bunds, kept in terms of vertical interval (VI) and horizontal interval (Ill) is shown in table 10.

Table 10: Spacing or bunds in different slopes

Sl. No	Slope % of land	VI (m) (Vertical interval)	HI (m) (Horizontal interval)
1	0 to 1	1.05	105
2	1 to 1.5	1.20	98
3	1.5 to 2.0	1.35	75
4	2.0 to 3.0	1.50	60
5	3.0 to 4.0	1.65	52

Cross section of bunds depends largely upon the type of soil. The commonly adopted standards of cross section are shown in the table 11.

Table 11: Cross section or a bund

Sl. No	Type of soil	Top width (cm)	Bottom width (cm)	Height slope (cm)	Side section (ratio)	Area of section (sq m)
1	Very shallow soil	45.0	195	75	1:1	10.00
2	Shallow soils	45.0	255	82.5	1.25:1	13.75
3	Medium soils	52.5	300	82.5	1.50:1	16.00
4	Medium heavy soils	60.0	420	90	2:1	24.00

3. Graded bunding

Graded bunds are used for safe disposal of water. They are not built necessarily along contours. In high rainfall (60 cm per annum) areas, especially where soil is relatively impervious, safe, disposal of excess water is necessary. A uniform and slight slope is given along with the length of the bunds which are connected to an outlet. Water moves towards outlet and is disposed off safely. The dimensions and slope of the water disposal channel or outlet are so constructed that it will keep the flow of water within non-erosive limits. Capacity of the channel should be determined according to the rate of run-off. Depending on the width of the base of bund, bunds are of two kinds: broad based bunds and narrow based bunds. Their adoption depends upon local soil and agro-climatic conditions.

4. Basin leaching

In this method, a number of small basins or water reservoirs are dug out across the slope along contours. Rain water, running down from the slopes is captured in these basins and collected. This water can be utilized by the plant growing towards the upper side of the basin. Basin making is very useful on hilly slopes where hard rocks lie below the surface of the soil and where establishment of saplings is the main concern.

5. Sub-soiling

In slightly sloppy fields containing hard clay pan in lower layers of the soil, sub-soiling or deep soil turning is a useful practice. Sub-soiling revives the productivity of land. In this method hard sub-soil is broken deeply by means of an instrument called sub-soiler and soil is partially turned or shaken. This process promotes absorption of rain water in the soil and makes the soil loose enough to permit unhindered growth of root system.

6. Gully control

Gully formation is the result of severe erosion. Reclamation of gullied landscape requires special structures and techniques which are very costly. The cost is, however, justified on the basis of protection to adjacent or downstream land, reservoirs, building etc. and additional income which can be generated from reclaimed land in the long run.

Small and medium gullies can be corrected by simple labour intensive measures such as land-filling. But the extensive deep gullies which have destroyed the whole landscape cannot be corrected by the simple measures. For them, other mechanical and vegetative measures have to be employed in the catchment area itself. Catchment area is the geographical area where from water runs-off towards the mouth of gully. Retention of run-off water in the catchment area itself and its diversion and safe disposal into other direction virtually reduces water pressures on gullies. Measures such as contour cropping, strip cropping, bunding, terracing and good crop management should be adopted in catchment area with a view to reducing run-off. Complete removal of run-off into the gullies is possible by diverting the run-off from above the gully mouth. A close growing vegetation can be established which filters out moving soil particles. The capacity of diversion channel should be based on rainfall data of about 10 years in order to ensure its stability. The channel should have an outlet into a well protected natural drainage way.

In the zones of high rainfall and extensively gullied lands, it may not be possible to keep the run-off water off the gullies by retaining it on watershed or catchment area and diverting it from above the gully heads. In this situation, run-off water has to be conveyed through gullies;

Some deep and wide gullies have to be convened into safe drainage ways and the run-off water of corrected land is' conveyed into them. Following measures can be adopted to reduce the loss of water as well as soil through the gullies.

7. Establishment of sodded earth fills

Sodded earth fill means earth fills reinforced with deep rooted grasses or earth with patches of grass. In the gullies, earthen embankments are created at appropriate spacing and deep rooted hardy grass is allowed to grow over them. Sodded earth fills should be spaced in such a way that the top of each will be as high as the base of the next one above. Maximum side slopes kept are 3:1 on the upstream side and 4:1 on the downstream face as shown in Fig 3. The height is kept around 45 cm. The top of the fill should be low in the centre and should gradually curve upward to meet the gully sides. It should be solidly sodded. In big gullies, plantation of tall vegetation such as trees, shrubs and vines can be recommended.

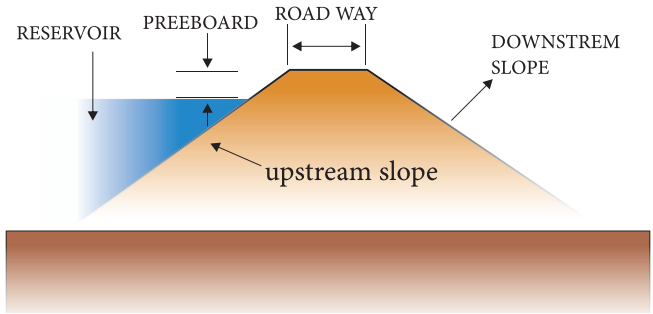


Fig 3 Structure of a bund

8. Temporary check dams

In this method also temporary earthen embankments are erected across the gully bed. These embankments or check dams are spaced in such a way that the top of one elevates

to the base of another located upslope side. The height of the check dams ranges from 50 to 75 cm depending upon the amount of annual run-off in the region. Check dams are seeded with protective vegetation. Water retained towards the upper side of the check dams, supplies moisture to the roots of growing vegetation in dry periods. In the course of time whole gully gets thickly vegetated and water loss and soil erosion is markedly reduced. Repairing of check dams is, however, needed at an interval of 4-5 years. Where there is strong flow of water cement or stone structures are necessary for the construction of check dams.

9. Woven wire dams

These are also only temporary aids in the establishment of vegetation for the control of erosion, To construct the woven wire dams, a row of posts is set along the curve of the proposed dam at about 1.2 m intervals. The pole is pierced about 60-90 cm. deep. Heavy gauge woven wire is laced with the posts at 25-30 cm apart, starting from 25-30 cm. above the bed level. Paddy straw, sugarcane tops, maize stem etc. are placed upstream side and then packed with soil along the posts. The centre of the dam should below enough to provide the necessary spillway capacity.

10. Loose rock dams

In the places where rocks or stones of appropriate size and shape are available, construction of loose rock darns is economical. The poles are set and wires laced with them in the same manner as described above. Stones are then encased with woven wires rather than putting straw. To construct a dam, a trench is first dug in the gully to a depth of about 30 cm. This forms the foundation upon which the stones are laid in rows and are ‘brought to a requisite height. The centre of the dam is kept lower to allow water to pass

over. In order to avoid erosion of the site where waterfalls some stones should be placed on that site.

11. Plank dams

In building these dams, the posts are set in a row across the gully to a depth of about I m and about 1.2 m apart. The posts should be so arranged that one of the intervals between them will occur in the approximate centre of the gully to form spillway. After the posts are set, a narrow trench is dug along their upstream side. The trench is made about 30 cm. deep and just wide enough to permit placing of the headwall. A notch type spillway of required size is cut out after the dam is constructed or a suitable opening can be left at the head wall during construction. Towards the upstream face of the headwall enough earth fill is made. The fill should have slope not steeper than 2: 1 and should extend well up to the gully banks. The sides of the plank can be fixed by stones loose rocks, bricks or sodded earth.

12. Permanent structures

Permanent gully control structures involve use of masonry, cement, bricks, concrete, etc. Three permanent structures are mainly constructed for gully control. They are (a) drop spillways (b) chute spillways and (c) drop inlet spillways. Construction of permanent structures should be avoided as far as possible since they incur heavy expenditure and require a high technical skill. Only in extreme cases of erosion where effective control by other means is not possible, permanent structures can be erected.

13. Contour trenches

Trenches along the contour line control rush of rain water and thereby control the soil erosion. The width and

depth of the trenches be maintained one foot while any convenient length can be adopted. Some trenches can be the full length of the contour line.

CONSEQUENCES OF SOIL EROSION

Soil erosion affects the crop production and public life in many ways. Following are the few important consequences 9f soil erosion.

1. Loss of productive soil

Under natural conditions of vegetative cover, nature takes 100 to 500 years or more to generate one inch thick layer of top soil. We are losing the nature's efforts of thousands of years in a matter of just a few days by inducing accelerated erosion (erosion due to human interference). The most fertile parts of the soil the clay complex and the organic matter complex -which serve as the reservoir of nutrients, are washed away from the surface soil. A cream of soil is skimmed off and coarse unproductive fraction is left to support, plant growth. In the course of time crop yield goes down miserably and ultimately agricultural value of the soil is lost.

2. Loss of water

Inadequacy of water for crop use is the biggest limiting factor in maximizing the crop yield in our country. Only 30% of the total arable land is irrigated in our country. In the remaining 70% dryland or rainfed land, provisions of water conservation are woefully lacking. A vast amount of rainwater carrying a huge amount of the productive soil is lost to the rivers, canals and ultimately to the ocean.

3. Incidence or flood and drought

Soil erosion aggravates the incidence of flood and

drought. The soil particles carried by water are deposited in river beds and canal-bed. With the passage of time, rivers and canals get shallower and shallower. Consequently, the water table in rivers and canals rises and causes flood in low lying areas. On the other hand, due to over use and mismanagement of soil, unnoticed loss of fertile soil continues. Soil loses its capacity to support vegetation. In that case, hydrological cycle is broken and clouds laden with water fail to rain. Consequently, the drought takes place.

The incidence of floods and droughts induced by excessive felling of forest trees can aptly be explained here. Excessive felling of trees (i.e. vegetation) results in increased loss of soil which is deposited in river beds resulting in flood. Absence of vegetation results in extremely low content of moisture in the atmosphere of that area. Consequently, hydrological cycle is imbalanced and drought takes place.

4. Deposition or sand on fertile land

In some parts of the plains, fertile lands have been made unproductive by the deposition of coarser material brought down from the hills by streams and river. Likewise in some parts of Rajasthan and other states, wind erosion has left fertile soils unproductive by depositing sand in thick layers over them. Formation of sand dunes (the huge depositions of sand over fertile land) is the typical example of this kind.

5. Silting of lakes and reservoirs

Soil erosion from catchment areas of reservoir results in the deposition of soil into the reservoirs, thus reducing their storage capacity and shortening their economic life. Excessive silting rates have been observed in a number of major reservoirs associated with the river valley projects in India. Most of the major multipurpose

reservoirs constructed in different regions of India have been designed on the basis of sedimentation inflow into them (from catchment area) to the tune of 3.52 hectare meters per 100 sq. km. of the catchment area or watershed area (i.e. as much soil from 100 sq. km. a as can form one mater thick layer in 3.52 hectare land area). But the rate of siltation (sedimentation), observed in many surveys, is much higher. Sedimentation rate of some reservoirs, based on per 100 sq km area, is shown in table 12.

Table 12: Rate of siltation in some important reservoirs

(Hectare meter sediment/l00 sq. km watershed area)

Sl. No	Reservoir name	Sedimentation
1	Bhakra	5.05
2	Panchet	9.86
3	Maithon	15.25
4	Mayurakshi	18.8
5	Tungabhadra	23.5
6	Chambal	28.2

6. Lowering of water table

Due to run-off most of the water is lost to rivers and canals. Very small amount of water infiltrates into the soil. Therefore groundwater is not replenished. It results in lowering of water table in the course of time.

7. Pollution

Soil contains some chemicals which are toxic in nature. The places receiving fertilizers and pesticides often contain a large amount of toxic chemicals. Run-off water carries these chemicals to reservoirs, lakes, canals, rivers and finally to ocean disturbing all aquatic life. The excessive built up of these toxic chemicals (eg. nitrates) is very detrimental

to aquatic flora and fauna. Even the community wells and ponds are not left unaffected thereby posing a health hazard.

8. Miscellaneous losses

In highly erosive areas deep and extensive gullies may deshape the farm into many valleys and ridges. Even roads, building, bridges and fences may be affected. Violent winds in summer may pack the road with sand. Striking action of wind laden with soil panicles may bruise the tender plants and cause serious damage to the standing crop in the field.

9. Concluding remarks

In a country where about 640 crores of people are directly dependent upon agriculture, land is of an immense value. It would be crime against nature as well as millions of underfed Indians if we recklessly allow the loss of their precious natural gift i.e. soil. For a social activist, it should be a responsibility to build up awareness among the people so that they themselves are motivated to take preventive as well as curative measures. At least the low cost conservation measures such as farming across the slope, strip cropping, contour farming, crop rotation, etc. can easily be adopted even by the poorest among the poor farmer's community of the country.

SOIL CONSERVATION MEASURES

Watershed management at present is one of the most accepted form of developmental approach. It begins with the soil and water conservation but is expected to move on to the natural and human resource management and finally to community building. Water is the most essential item for every living being. Soil is a porous material and acts like a sponge capable of absorbing and retaining the water. Thus soil acts as the vessel in which water is stored in the nature.

This retained water is called soil moisture part of which is available to the plants. Therefore for the plants to obtain water from the soil there should be water stored in the soil. For this first of all the soil should be stored up or preserved. The question of soil conservation becomes most crucial because soil is very easily eroded within no time. At the same time it should be remembered that it takes hundreds of years to form one centimeter thick layer of soil.

Most of the cultivated lands are slopping and require one or more types of soil conservation measures. The topography and agro-climatic conditions are so varying in our country that one should have the ability to discern what type of soil conservation measures a particular land area requires. This means he should have a clear idea of the various soil conservation measures and their suitability to a particular geographical area where the soil conservation is a problem. One should have the ability to diagnose the type of soil conservation problem and to propose appropriate treatment to solve each problem. Often he should apply a combination of treatments in which case he should have a clear idea of the combined effect of various in the soil conservation measures.

Most of the cultivated lands need application of long term soil conservation measures followed by reorganization of land use pattern efficiently including son moisture conservation, improvement of soil productivity and cropping and farming systems.

There are many ways of conserving the soil. Numerically speaking there are about 58 ways of mechanical soil conservation, 13 ways of biological soil conservation and 20 ways of agronomic soil conservation. Often both the trainers as well as trainees get confused between the various types soil conservation measures. Some of them of

course are very much similar to each other. In the field level situation a combination of a number of soil conservation measures have to be applied. Therefore one should have the ability to decide which combination of soil conservation measures should be implemented. This chapter intends to enumerate all the possible types of soil erosion control measures and their combined applicability to various conditions of soil degradation and erosion. Several of the measures enumerated may not be found in the conventional literatures. They are collections from the field practices observed by me in many parts of the country.

As already mentioned there are mainly three broad types of soil erosion control: mechanical, biological and agronomic. Under each of these there are many types of individually different measures. The readers are strongly reminded that it is a combination of several soil erosion control measures drawn from the mechanical, biological and agronomic types that becomes effective in the actual field conditions.

We cannot change significantly the climate and the inherent soil properties of a place. But we can do something to modify the other factors of topography and vegetation to reduce soil and water losses. However before we discuses each method we need to know the factors that should be taken into consideration in determining the type of soil conservation measures.

A. Factors to be considered

The following factors and the mechanics of erosion by water and wind are to be assessed before we implement any of the soil conservation measures. They are briefly described here.

1. Physiography

The physiography refers to the size, shape, relief, drainage, mean elevation, land slope etc. Both the volume and rate of runoff increase as the size of the watershed increases. The size of the watershed is an important factor to compute the peak rate of runoff which is essential for the designing of the drainage channel.

The longer and narrower the watershed the time of concentration of water (water retention in the water shed will be longer and lesser will be the runoff. Relief designates the elevation difference between any two reference points on the basin with respect to outlet elevation. Greater the elevation lesser will the concentration effect. At the same time longer the distance between the points greater will be the concentration effect or runoff water. Ultimately the combined effect of the elevation difference (slope factor) and the total length (length of slope) between the points will be the actual concentration effect.

Land slope has major implications for the land use. The speed and the extent of runoff depend on slope of the land. Greater the slope more will be the velocity of the water flow and still greater win the erosion of the soil. The complex mathematical expressions of the multiplying effect of the slope on the velocity, erosivity, the quantity of soil eroded and the particle size is expressed here in words as follows.

"When the slope is increased by four units the velocity of water flowing along the slope is doubled; if the velocity is doubled the energy and the consequent erosivity is increased four times; the quantity of soil eroded is increased by 32 times and the size of the particles that can be transported by pushing or rolling is increased by about 64 times." '

When the slope is more the number of contour lines will be more per unit area. Based on this relationship we can estimate the percentage of slope of a given area using the

following formula: S = MN/A x 100, where S is percentage of slope, M is total length of all contours within a watershed in meters, N is the contour interval and A is the area of the watershed (m^2).

The degree of slope determines the land use for annual crops, plantation crops, land reclamation, depending on soil depth, stoniness, etc. Hence the length and degree of slope is important parameters to be considered in the watershed management. Roughly we can say that up to 3% of the area is good (or bunding, 4-7% slopes is suitable of contour bunding, 8-10% slope for broad base terrace, 11-15% slopes for broad terrace, 16-20% slope for broad bench terrace, 21-25% slope for bench terrace, 26-30% for narrow bench terrace, 31-50% slope is suitable for horticultural and fodder trees and between 51-100% slope the land should be used for planted forestry for fire wood and small timber trees and above 100% the land should be left for natural forest. This division is arbitrary and is based on the practical experience in the field. These land use recommendations are perhaps the best an environmentalist can practice and recommend to others.

The total rainfall and the drainage density are factors that need to be considered for the watershed management. The factors affecting drainage are related to the susceptibility of soil to erosion, runoff pattern, sedimentation and locating erosion control structures and erosion itself.

$$\text{Drainage density} = \frac{\text{Total length of all streams (km)}}{\text{Catchment area (km}^2\text{)}}$$

The drainage map of an area may serve as a beneficial tool for the understanding and the preparation of the erosion assessment. From the drainage map we can understand the

drainage pattern of an area referring to the design of the stream courses and their tributaries. The drainage may be fine, medium or coarse textured depending on the type of soil. Clay soil will exhibit finer drainage structure while the sandy soil will show coarse structure. Drainage patterns can act as guidelines to locate vulnerable areas requiring different kinds and degree of soil conservation measures.

2. Soil properties

Soil properties refer to soil series and soil phases, physical, chemical and biological properties, hydraulic soil groups and soil moisture regimes. Based on the runoff potential there are four hydraulic soil groups: (a) low runoff potential, (b) moderately low runoff potential, (c) moderately high runoff potential and (d) high runoff potential. The runoff very much depends on the infiltration and permeability of the soil.

3. Vegetative cover

A dense vegetative cover is the most powerful means to reduce the soil erosion. In relation to the vegetative cover the following hydrologic conditions may be identified: (a) poor (heavily grazed or regularly burnt, litter, small trees and brush are destroyed), (b) fair (grazed but not burnt, there may be some litter but these are not protected), (c) good (protected from grazing, litter and shrubs cover the soils).

4. Land use practices

A record of the present land use practices followed by the farmers in a region is essential for further planning and reorganization of land use according to its land use capability classification, to get sustained production.

5. Nature and distribution of rainfall

Rainfall data is collected at different locations in the watershed and the mean is estimated. Besides total annual average the duration, intensity, frequencies etc. of the rainfall are also important information for the watershed management.

6. Prediction of peak run off rate

The peak runoff refers to the maximum level of runoff happening during a period of very high storm which occurs once in several years. In soil and water conservation measures, the design of hydrologic structures, quantitative estimates of runoff rates, volumes and distribution are to be worked out. The channels and other structures are planned in such a way that they will be able to carry maximum runoff which can be expected in a specified recurrence interval.

7. Floods and droughts

Related to the peak runoff is the flood situation which also occurs either every year or once in few years. Needless to say that the soil conservation measures implemented should be able to withstand the flood waters. Whereas, in the case of drought the soil conservation structures should be such that they store sufficient moisture in the watershed area to tide over the drought period. Therefore we should have sufficient data on the flood and drought occurrence in the watershed area.

8. Socio-economic factor

The watershed management begins with the implementation of soil conservation structures. But it should cross over to the economic **programmes** and finally it should culminate m social development programmes. Even in implementing the economic and social programmes

the cultural factors are to be taken into consideration.

B. Mechanical Measures

The mechanical measures for soil conservation, consists of any structure that is erected to hold the soil and thereby prevent the erosion. They are described as follows.

1. Bunds

Bunds are ridges or embankments or long and narrow projections constructed on the surface on the land at selected places and in selected directions. They are constructed with a number of materials, in different. sizes, shapes and heights. In this chapter the types of bunds described are with reference to the construction material and way of construction. Bunds are also constructed in contour or graded contour line.

a. Mud bond

The mud bunds are constructed using the soil. This is constructed when the slope is minimum. This is common in farm lands and in places where rainfall is average and above. The mud from the lower side of the proposed bund is dug up and placed in position to make the bund. For more details about bund making the readers may consult the Booklet No. 593 on "Bunds and Terracing". In places where there is average and above average rainfall there should be drainage from the plots in order to drain out the water.

b. Loose rock bond

In loose rock bunds instead of soil, rocks are used. The rocks are piled up in the form of a bund. Rocks of different sizes are arranged in such a way that the small ones are fitting in between the big ones. This is constructed in areas where the rainfall is less than average and the rainfall is

erratic. Stone bunds are constructed in places where there are plenty of stones available at very cheap rates and to withstand the sudden on rush of rain water. They reduce considerably the velocity of the rushing water. However the water is not retained some soil may be retained.

c. Loose rock cum soil bund

In this type the space between the rocks is filled with the soil which acts as a cementing agent. Besides the above mentioned advantages this type is able to retain the soil also.

d. Bund cum vegetation

Trees; shrubs or bushes are planted on the top of the bund; or on one side of it, By doing this the bunds are strengthened.

2. Walls

Walls of different heights are made in certain places for the conservation of soil and water. They are of different types.

a. One sided mudwalI

These are modified bunds constructed on land have more slopes than the places where bunds cannot be constructed nor terracing can be done immediately. The down side of the bund is beaten and pressed in such a way that it looks like a wall. The upper side though shows bunded structure merges with the land on the upper side. This is possible only in clay soil. Grass is allowed to grow on the side of the wall so that the waIl will be durable.

b. Double sided mud wall

In this type the wall is built higher and hence both the

sides have to be built by beating and pressing the soil to make a compact wall. By growing suitable grasses we can maintain the wall durable. It is also highly advisable to cover the double sided wall with any material to protect it from erosion due to rain.

c. One sided stone wall

Instead of mud stones are arranged at an angle corresponding to the angle of retention. This is much more durable than the mud walls.

d. Double sided stone wall

Stones are arranged on both sides of the wall with moist soil pressed and compacted in between.

e. Loose rock wall

Rocks and stones are arranged without any soil of cementing material in the form of a short wall. This is useful to check and reduce the velocity of the rushing water and soil coming along with it under erratic rainfall conditions.

3. Terraces

Terrace is the cut and leveled portion of the slope. Depending on the degree of slope the width of the terraces will vary. Greater the slope lesser will be the width of the terrace. Depending on the width of the terrace there are different types of terraces. With reference to slope the terraces may be bunt in three ways: leveled terraces, inward slopping terraces and outward slopping terraces. For irrigated crops like paddy leveled terraces may be better. When one needs drainage through channel then inward slopping terraces are better. But if the drainage is natural then outward slopping terrace is better.

a. Broad base terrace

Generally broad base terraces are made on land slopping between 8-10 per cent.

b. Broad terrace

Broad terraces are constructed on lands slopping between 11-15 per cent.

c. Broad bench terrace

These are lesser in width and are constructed on lands with slopes ranging between 16-20 per cent.

d. Bench terrace

These are still narrower terraces constructed on lands with slopes ranging between 21-25 per cent.

e. Narrow bench terrace

These are terraces of least width and constructed on slopes ranging between 26-30 per cent.

d. Continuous terrace

When the terracing is done along the whole length of the contour it is called continuous terraces.

e. Broken terraces

When terracing is done in a broken not continuous form it is called broken terraces. They can also be called intermittent terraces.

f. Interlinked terraces

In this the terraces are constructed in such a way that one terrace leads or linked to another terrace on either side in the upward and downward way. Each terrace is shorter in width and length. The design looks like criss-cross arrangement of the terraced beds. The linkages between

the terraces help in moving bullocks and implements up and down from one terrace to the other on the slope. Also it forms a zigzag path for the people to go up and down the slope.

g. Intermittent square terrace

These are square shaped platforms cut on the slope to plant trees or to conserve soil and water around the trees already planted. The trees may be fruit trees, plantation crops like coconut, rubber, cocoa, coffee, pepper, nutmeg, clove, aracanut etc. The trees may be planted in contour line.

h. Platform terrace

When the intermittent square terraces made for a row of trees planted in a contour line and extended both sides the whole thing looks like a platform cut across the slope. This is very common for plantation crops planted in contour line.

i. Half circled terrace

Instead of square shaped intermittent terraces for the trees half circled terraces are cut on the slopes.

4. Gully check

Gully is a common term used for a variety of soil erosion effects ranging from few centimeters to three meters in depth and up to 18 meters in width. In some places gullies are called channels or nallah in Hindi varying from small channel to very big ones. The gullies are classified into very small gullies, small gullies, medium gullies and deep and narrow gullies. This classification according to me is too broad. For example very small gully according to the conventional classification varies from few centimeters to

three hundred centimeters. The range is too much. Similarly in the other classification too the range of depth and to some extend the width is too much. The gullies may be with or without perennial flow of water. The barriers created for checking the soil erosion through various types and sizes of gullies are commonly called gully plugging or gully checks or channel/nallaha checks/ bunding in general.

Gullies with water flow are called streams and the checks made in them are called check dams. While checks that are made in gullies with flow of water only during the rains (seasonal) are called gully checks or gully plugs. Since the flow of water in the gullies is so much forceful the checks should be strongly constructed. The needed strength of the checks depends on the force of flow of water (quantity of water, percentage of slope, length of the slope, type of the soil etc. and duration of rain and flow. Therefore the strength of the checks should be varying by adopting suitable construction materials and method. The different types of checks described here are precisely according to their variation in their strength to withstand the flow of water. They can be constructed in a number of ways. Most of them are explained here.

The width of the checks obviously depends on the length of the checks. More the length greater will be the width of the checks. As a thumb rule we can say that for every 9-12 Inches length the width of the check should be one inch (1:9-12). Therefore for 10 feet long check 10 inches thickness is needed. However this will vary according to the place and according to the force of flow of water. The width of the checks given here does not include the width of the foundation. In some cases the design and nature of the foundation should be given very serious consideration. Otherwise the gully checks will not survive very long. The

gully checks should be permanently built. Only then it will achieve attain its purpose of preventing the increase in the depth and width of the gully and also level the gullies. Therefore it is highly recommended that only permanent. Checks/structures should be built across the gullies.

In a gully there will be a number of checks installed at regular intervals (distance between two successive checks). The main principle to be followed under such conditions is to maintain proper interval between the checks. The top of the lower check should be at least one foot higher than the ground level of the upper check. Anything less than this will result in' the erosion of the soil. The height of the checks will be deter- mined according to the percentage of slope and the distance between two successive checks and the depth of the gully. For a fixed height of the check the interval will vary with variation in the percentage of slope: greater the percentage of slope lesser will be the interval between checks and vice a vice. Similarly for a fixed distance the height of the checks vary with the percentage of the slope of the gully. The length of the checks depends of the width of the gully. The type of the gully checks described here are in the order of decreasing strength.

a. Concrete checks

When the force of the flow is very high strongly built concrete checks are necessary to control the gully erosion. Sufficient foundation should be laid at the bottom and on the sides. For the reinforced concrete checks normally 1:3:6 to 1.:4:8 cement, sand and metal mixture is used for the construction of the concrete check.

b. Sized stone and cement checks

Well sized stones are used to construct the gully checks. Well constructed checks are as strong as the concrete

ones. The cement mixture should have the proportion of 1:4 cement and sand. Instead of sized stones we can use unsized stones also.

c. Brick and cement

In this type well baked bricks and cement are used to construct the gully checks.

d. Loose rock double sided wall with cement

Instead of the sized stones irregular stones are used for the construction of the checks. The stones are arranged in such a way that both sides of the wall will be in the same level. The stones are jointed with the mixture of 1:4 cement and sand.

e. Loose rock double sided wall with pointed cement

Checks are made of any irregular shaped stones collected from the vicinity and are arranged in such a way that there is a wall on both sides. The space in between may be filled with small stones or soil. Finally the space between the stones is filled with the cement

f. Loose rock double sided wall without pointing

These type of checks are made in places where the force of flow is less compared to the previous cases and which allow the water to drain out through between the rocks while retaining the soil. Eventually the spaces between the walls will get filled up with the incoming mud and the wall becomes impervious.

g. Loose rock one sided wall pointed with cement

The one sided walls are more suited to gullies with greater percentage of slope and in cases the upper side of

the gully check is leveled at the time of construction. The construction of this type of wall is similar to the above mentioned one except that the stones are arranged in level on one side only. Obviously this type of wall is less strong than the previous one.

h. Loose rock one sided wall without pointing.

The construction is same as the above mentioned ones except there will be no use of cement. On the upper side of this wall is filled with soil and stones.

i. Brush wood checks

This is a fencing structure across the gully and usually made in places where plenty of wood is easily available. The structure consists in vertically planted posts and the horizontally fixed long poles. (Hereafter posts refer to vertical structures and the poles refer to the horizontal, structures). The vertical and horizontal structures may be made of any material such as concrete, iron, live wood and dead woods. The space between the vertical posts and the horizontal poles can vary from very close to several feet apart. The space between the vertical posts and the horizontal poles will be covered with twigs, leaves or any other vegetative material so that the soil eroded in the beginning will come and settle against them making a barrier to further soil erosion. In some case the space filled at the time of the construction itself. Whatever be the material of construction the brush wood check dams should be durable. When the brush wood check is made of live wooden material it can considered as a biological measure also. However it should be remembered that here we are discussing the mechanical structures. There are several types of brushwood dams as explained here.

a. Live posts and poles

The branches of trees that sprout in to new trees are planted as post. The horizontal poles are planted into the soil on both sides of the gully and tied to the posts. Both the posts and poles strike roots and sprout into branches forming an interwoven vegetative structure. Obviously this can be done, only in deep and narrow gullies having deep soil layer from the top to the bottom of the gully and in places where easily rooting and sprouting trees are available.

b. Live posts and dead poles

The construction is same as explained before except that it can be constructed in places where the sides of the gullies are rocky or stony.

c. Dead posts and poles

Dead wood collected from the nearby areas is used to construct the brush wood checks.

d. Concrete posts and poles

Concrete posts and poles are either planted or constructed in situ to form the brush wood check.

e. Concrete posts and wooden poles

The concrete posts are constructed in situ or brought from the place of fabrication. The wooden poles are fixed horizontally.

f. Live posts both sides of mod bond

In this case a closely planted brushwood posts will be lining on both sides of a tapering and high mud bund constructed across the gully. In this case the posts planted are thinner than the posts mentioned above. They are branches of the trees which strikes root and sprout easily.

g. Dead posts both sides of mud bund

Instead of the live posts dead wooden branches of any kind of trees are used.

h. Conically planted double line posts

In this case the brush wood posts are planted in two lines at suitable distance but slanting towards each other in pairs and crossing at the required height of the check. When constructed it will look like a conical fencing. Reapers are fixed horizontally to strengthen the fencing. We can construct this type with live or dead posts including that of concrete and iron.

i. Straight and slanting line

In this type of brush wood checks two lines of brush wood posts are planted at a suitable distance. The posts in the upper side line will be planted straight while the posts in the lower side line will be planted slanting towards the upper line and each post in the lower side line will be crossing with the corresponding post in the upper side line at a height required for the brush wood. Reapers may be fixed horizontally to strengthen the brush wood structure. In this case also we can make it with live or dead posts including that of concrete and iron.

j. Sand bags

Sand bags are easy material for constructing checks where there is water flow in the gullies. The sand bags are arranged in such a way that they form a well shaped check across the gully.

k. Building sides

Often the sides of the gullies are prone to land slides or massive soil erosion causing the increase of the width of

the gully. By building the sides one can retain the gully and used as drainage or a channel.

l. Paving the bottom

The gullies could be paved with stones or bricks in case one wants to retain the gully and use it as a drainage or channel.

5. Gibbon structures

The structure of gibbon constructions consists in having a very strong wire mesh holding small or big boulders in the form of a bundle. The shape of the bundle may vary from round to cylindrical. Gibbon structures can take the place of bunds, walls of terraces, sides of channels and gullies, checks, pillars etc. and are usually made where strong foundations are not possible to make the above mentioned structures. Galvanized wire mesh is used in the case of permanent gibbon structures whereas for temporary structures ropes and wires of lesser strength can be used. Based on the shape and material of construction we can identify several types of gibbons.

Gibbon structures can be used for gully checks, for one side walls to prevent landslides, to reinforce the side of the streams prone to landslides, to make double sided walls, stone path ways etc.

a. Galvanized wire and stones

Galvanized type of thick wire is used. Depending on the size of the stones the mesh size is decided. The mesh is spread on the ground in the place where the gibbon is to be constructed and the stones are piled up in the shape one wants. Then the mesh is taken over the pile and fixed firmly using proper wire tightening instruments so that all the stones in the pile will be held firmly in place. It will look

like a bundle of stones but in any predetermined shape. We can construct gibbon structures in any size and shape and length. We can also construct them in layers one above the other in the case of permanent gibbon structures.

b. Ropes and stones

Any type of rope material is used in the place of galvanized wire mesh. Though theoretically this is possible for practical purposes we cannot rely on this. Soil conservation is a long term planned activity. Therefore gibbon structures with ordinary rope material will not be useful for soil conservation.

c. Gibbon pillars

Wire mesh or rope mesh made in the form of cylindrical shape is filled with stones and finally when it is filled it will look like a pillar. Using these pillars further horizontal structures can be attached and made strong. Gibbon pillars can be used for constructing temporary check dams.

6. Mechanical water channel

The constant or frequent flow of water through the mud channels, whether irrigation or drainage, usually causes erosion of the soil in a massive way. The channels can be protected in several ways. The most common ones are explained here.

a. Concrete channels

If the channels are big it is advisable to use reinforced concrete at the bottom and the sides.

b. Cementing

If the channels are small cementing the bottom and the sides would be sufficient for preventing the soil erosion.

c. Paving

Paving the bottom and the sides of the channel with stones, bricks, tiles etc. will help in controlling the soil erosion in irrigation and drainage channels.

d. Stone spreading

Spreading boulders on the edges of the streams and water ways is another effective way of controlling the soil erosion.

e. Gravel spreading

If the water channel or drainage is very gently sloping or almost leveled spreading pebbles or gravel would be enough to control soil erosion.

7. Trenches

Trenches are dug in different patterns across the slope to control the soil erosion by trapping the runoff water. On lands more than 25% slope trenches should not be made. In other words for a two feet wide trench the difference in height between the upper and lower edges should not be more than half a foot. Trenches are constructed in places where more rain water is received than that can be held by the bunds. Further the number of trenches dug in a unit area is more when the rain fall is high. Trenches of about one to two feet deep and wide are dug in any convenient direction or strength. For the control of the soil erosion trenches are made along the contour line. The following are some of the important types of trenches.

a. Continuous

When a continuous trench is made in contour line it is called a continuous trench.

b. intermittent

These are trenches of shorter lengths dug in the contour or non-contour line with a certain amount of gaps in between. Where continuous trenches cannot be built due to rocks or stones intermittent trenches are dug.

c. Intermittent alternate

When the intermittent trenches of two successive lines are alternated in position (gaps and treches) they are said to be alternative.

8. Pits

Pits are either round or square. Pits can be dug on land (up to 33% slope.. Pits are more suitable where even intermittent trenches cannot be dug. This happens when the land is too stony or rocky. The pits are dug wherever possible.

9. Others

Besides the above mentioned soil conservation measures there are a few mechanical structure constructed for the control of soil.

a. Check dam

Small dams built across the perennial streams to store or divert water and ultimately to control the soil erosion are check dams. Check dams may be built of mud, concrete, stones, bricks etc. For the details of construction of check dams the readers may refer to Booklets Nos. 573, 574, 579 & 576 on Investigation and planning, Design, Construction and Maintenance Earthern dams. In the case of check dam across the perennial streams the over flow is allowed by the side of the dam over a structure called spillway.

b. Anicuts

Anicuts are like check dams except that the overflow is allowed over the dam itself. No spill way is constructed as in the case of check dam. Water is impounded on the upper side of the anicut. Since the water is flowing and falling to the ground there is all possibility of cutting the soil at the foot of the anicut. In order to prevent this, a check wall of about 2-4 feet called "shoe" is made a few feet away from the spot waterfalls at maximum flow. This is built of concrete or stones with cement in such a way that water falling from the anicut can be stored at a certain height of 2-4 feet. This water acts as an absorbent of the force of water falling.

c. Wiers

Wiers are structures constructed across the channels and streams. These structures have rectangular of triangular shaped notches to allow the water to over flow. Besides soil erosion control wiers are also used to measure the quantity of water flowing through the streams or channels.

10. Ridges and furrows

Ridges and furrows are usually temporary mechanical structures though we can have them permanently too on a gently sloping land with plantation crops, fodder crops, horticultural crops or forestry plantation. In seasonal cropping the ridges and furrows are temporary and small in size. In the permanent cultivation the ridges and furrows are made big. The effect of the ridges and furrows are suitable in low rainfall areas for the conservation water. According to the shape of furrows and ridges they may be classified into three types.

a. V-type

The ridges and furrows are made in such a way that

between two ridges the furrow will be in the shape of English letter V. In this design the ridges and furrows will be small in size and the ridges will have sharp edge on the top.

b. U-type

The ridges and furrows are made in such a way that the space between two ridges will be in V-shape. The top of the ridge will be round. The ridges will be bigger than the V-type. The bottom of the furrow will also be round.

c. L-type

In this type the furrows and ridges will be still bigger and the space between two ridges will be wider in the form of a channel with L-shaped sides. The top of the ridges may be fiat with steep sides or broadly round. The furrows will be flat at the bottom forming like a broad channel.

C. Biological Measures

Biological agents like trees, shrubs, bushes, grasses are used in controlling the soil erosion. These are planted alone or along with mechanical measures. The trees, shrubs, bushes and grasses are planted in such a way that they are able to control the erosion to a great extend. They may be planted alone or in combination. However it should be remembered that the biological measures will have to be applied along with the mechanical measures in the areas where perennial cropping systems like forestry and plantation crops are cultivated. Whereas where seasonal cultivation is done one should; follow a combination of mechanical, biological and agronomic measures.

The various measures under biological control are so similar that one tends to over simplify them both in the understanding and practical application resulting in the

failure of the programme. Each individual measure will be dealt here even though they are very much similar.

1. Tree plantation

Land above 30% slope should not be put under seasonal cultivation and the land above 45% slope should always be put under perennial forestry which should never be subjected to clear felling. One can only go for selective felling of trees in areas above 45% slope. But in some areas like origin of springs and streams should be kept under perennial natural forest at least 50 meters radius of the origin. From this area no felling should be done at all. Similarly areas which are so steep no felling should be done.

A word about selective felling is also necessary. Some of the ideas about selective felling will be too much for anyone to digest. However the ideas have to be projected before they are to considered. If we want to cut and fell a tree even selectively on to the ground some people have to go on the ground to the spot of the tree; it has to be cut manually or using mechanical saw; the tree will fall to the ground crushing some other trees, shrubs and bushes; then the branches have to be chopped and left in the forest if we want only the trunk; but if we want the branches also we have to cut them into manageable size. Then the trunk has to be dragged down to a place convenient enough to saw it into sawn timber or to load it into a truck. In some cases a road has to be -constructed to the spot of the tree cut. In all these cases there will be unavoidable erosion of soil.

Therefore it is highly advisable that above 45% slope selective felling of trees is done by means of helicopter. Helicopters should be used for people to slide down to the exact tree to be cut, chain the tree to the helicopter and then saw the trunk. As the trunk is fully cut and detached the

helicopter should lift the tree along with the person who cut the tree to a convenient place, in the plains for chopping the branches and to saw the trunk into timber.

In this case all the branches, leaves, bark and waste from the sawing of the timber can be utilized. In other words every bit of the tree will be utilized. This method apparently looks very expensive. But if we calculate the cost of irreparable harms of soil erosion due road construction to the felling spot or dragging of the timber down through the slope and the cost of road construction or employing an elephant to drag the timber down to the plains and to load and transport the timber by truck and the cost of laborers etc. and the value of the amount of time required to complete the felling of one or few tree in the traditional way and considering the additional income from the branches and the leaves selective felling by means of helicopter will be much cheaper. From the point of soil erosion control alone helicopter felling is cheaper.

The point being driven here is that under no condition any land above 45 % slope should be left without tree cover even for a day. Because, on that day, a storm can occur and thousands of tones of soil can be eroded.

Besides this tree cover on land above 45% slope is essential for the preservation of the springs and streams which are the sources of water for the big streams, small and big rivers.

It should be remembered also that the planting and caring of trees on land above 45% is very difficult or almost impossible. Hence the best way perhaps is to saw the seeds already and allow the natural growth of the plants except areas having transport and accessibility. After having said the basic policy with regard to the utilization of land above 45% slope let us see the various methods of biological

control of soil erosion. In all the tree plantation methods which are explained here the soil erosion is controlled by the canopy cover.

a. Random plantation

Trees are planted at random with the same type of trees or different types. The first is called monoculture and the latter is called polyculture. Areal seeding also result in random plantation. Random plantation is done in areas where spring originates, both sides of the streams and rivers and in areas where human beings cannot reach.

b. Monoculture

When the same species is planted in an area at random it is called random monoculture plantation.

c. Poly-culture

When different species are planted at random in an area it is called randomized polyculture.

d. Line plantation

Trees are planted in line and there are different types of line plantation such as (a) contour line, (b) square design, (c) rectangular, (d) hexagonal, (e) strip plantation, (1) boarder plantation on the boundaries, edges of the streams, canals, roads, bunds, boundaries of plots etc. Line plantation can be done only in areas where people can easily reach.

e. Block plantation

When trees of different species are planted in different blocks it is called block plantation. Each block may be of few to many acres. For commercial usages it is better to plant in blocks. Block plantation can also be done only in areas where people can reach easily.

f. Orchards

Planting of fruit trees is done according to the spacing required for each fruit tree. They may be planted in contour, square, rectangular or hexagonal design.

g. Wind break

Trees are planted as wind breaks across the direction of the wind. Wind breaks are planted on the edges of the seasonally cropped land and in orchards.

2. Shrubs plantation

Shrubs are trees small in stature. They can be planted just like the methods used for tree plantation. Shrubs are more commonly seen in the dry and scanty rainfall areas. Shrubs are also planted along with the trees on contour bunds. Planting trees and shrubs together on contour lines at regular intervals will help the control of soil erosion considerably.

3. Grass plantation

Grasses are excellent for soil erosion control. They can be planted on the bunds, on the edges of the terraces, on the side of the mud walls, in contour strips, on the boarders of the cultivated land, as pasture lands. Grasses are excellent for reinforcing the bunds; terraces and edges of the streams and canals.

4. Others

Other biological measures employed for the soil conservation are live brush wood check, pastures, live fencing.

a. Live brush wood

Fresh and green branches of trees that can be planted

by cutting are used as the vertical posts of the brush wood checks. When planted in the soil they grow like any other tree and form the permanent vertical structure of brush wood check. The branches can be planted fresh or after striking the roots.

b. Pastures

Pastures are areas where fodder grasses are grown to graze the animal. By maintaining pastures in a place we can control the soil erosion to a great extend.

c. Live fencing

Trees, shrubs and bushes are planted on boundaries of the plot to form fencing. When these fences are across the slope they contribute to the soil erosion control. Even if it is not across the slope or along the slope it will help in checking the soil erosion to some extend.

D. Agronomic Measures

The soil conservation measures adopted in the cropping systems and practices are called agronomic measures. In other words these are agronomic practices made into soil conservation measures. There are a number of the agronomic measures of soil conservation. However not all practices are suitable or practical in all the places under all the agronomic practices.

However it should be remembered that agronomic practices adopted for the seasonal cropping will not be of much use for the control of soil erosion in the long run. In other words it will be useful only for one season. After the crops are harvested there is always the chance of soil erosion if the soil erosion factors are prevalent. Therefore it is very important that for the long term soil conservation measures we should employ mechanical and biological

measures strictly before we apply the agronomic measures in any place. It should be again remembered that all the agronomic practices are not suitable for all the places. In each place according to the cropping pattern and cropping system not only the mechanical and biological measures of soil conservations are to be adopted but also the agronomic measures are also to be adopted.

1. Contour cropping

When rows of the crops are taken in contour line it is called contour cropping. This method is mainly adopted for the cultivation of seasonal crops at lesser slopes though contour cropping can be practiced for perennial crops in higher slope areas up to thirty per cent slope.

2. Contour strip cropping

Different crops are grown in contour strips on .the slope. For example maize is cultivated in strip consisting of a number of lines across the slope then either on the above or-below the strip of maize a strip of Arhar crop is sown. Then any vegetable crop is sown in another contour strip. Thus we can take as many crops as we want. In this method a deep rooted crop is alternated with a shallow rooted one. Soil erosion can be controlled to a great extend by this method.

3. Mixed cropping

A number of crops are planted at random mixed or in lines one crop after another. Theoretically speaking certain amount of soil erosion control may be there during the crop- ping period.

4. Multiple cropping

Multiple cropping is a method of growing several crops

in sequence on the same land during the same year. In other words in the same plot during the same year crops are grown during the kharif season followed by crops in the rabi season and zaid season. Because the land is always covered under I one crop or other the chances of soil erosion is less.

5. Multistory multiple cropping

Multistory cropping is a method in which mixed cropping of varying canopy heights are grown together. In this we can have double storey, triple storey and four storey cropping: Different crops of canopy height and width are adjusted within the same land to maximize the use of land area and the air volume area.

The principle in the multiple cropping is to plant the tallest crop in the maximum distance between which the next tall crop is planted at the middle. The next tall (third in height) crop is planted in the middle of the first tallest crop \ and the second tallest crop. The next tall crop is planted in between the second and the third.

In the multiple cropping it should also be noted that out of the three or four crops at least two should be perennial and the rest seasonal.

The following examples will make the point clear.

a. Coconut, with cocoa-banana-fodder grass for coastal areas
b. Neem -guava -pomegranate -ground nut for dry areas
c. Subabul -citrus -berseem for temperate areas
d. Sapota -guava -banana -fodder grass for irrigated areas
e. Sheesham -sapota -citrus -berseem for temperate areas
f. Drum stick trees -guava -lime -pine apple

g. Jackfruit + coconut -aracanut -clove -banana – pineapple for humid areas

h. Aonla -custard apple -periwinkle- aloe vera for very dry areas

h. Pear -orange -plum -straw burry for hilly areas

i. Mulberry- Karonda -Banana -lucero for temperate areas

j. Date palm -casuarina -bur -aloe vera for desert areas

k. Other similar combinations

6. Organic farming

Addition of organic manure increases the binding capacity of the soil particles providing some sort of erosion resistance.

7. Silvi-pasture

Silvi-pasture means cultivation of trees and grasses in the same place. Due to the tree cover and the grass cover the impact of the rain and other erosion agents on the soil will be minimal.

8. Ley farming

In ley farming crops are grown in between two year duration of pasture cropping.

9. Alley cropping

In alley farming crops are cultivated in between rows of trees which are planted at suitable distance to take seasonal crops.

10. Agroforestry

Agroforestry means growing trees on land where crops are grown. The difference between alley cropping

agroforestry is that alley cropping the trees are planted in lines at definite distance. Whereas, in agroforestry, the trees are planted at random and in the gaps among the crops, on the edges and corners of the plots

11. Mulching

Mulching is covering the soil surface with any biomass or sheets. By this the soil erosion is controlled in the cropping land.

12. Minimum tillage

Stirring and cultivating the soil increases the soil erosion. Therefore practice of minimum tillage is recommended "to reduce the soil erosion in the cropping land.

13. Cover cropping

Cover crops are grown to cover the soil surface and thereby reduce the soil erosion and retain the moisture in cropping land.

14. Green manuering

Incorporation of green leaves into the soil is called green manuering in general. It can be carried out in the following ways.

a. In situ

Any green manuering crop is grown on the same plot and when they are grown up they are ploughed and incorporated into the soil. Usually legumes are grown for in situ green manuering.

b. Applying green leaves

Green leaves are brought from outside and applied on the land: The leaves may be of legumes or non-legumes.

15. Perennial cropping

Growing perennial crops like fruit and plantation crops on lands which are prone to erosion will considerably reduce the soil erosion.

16. Dibbling the seeds

Placing seeds of trees, shrubs and bushes in holes made by a peg or a stick at regular intervals in a line is called dibbling. In this method there is no need for ploughing. Similarly we can dibble seedlings also.

17. Planting potted plants

A number of crops (trees, pulses, vegetables, oil seed crops) can be grown in pots or poly-bags in nurseries. They can be planted in the field along with the mud balls

18. Spot planting

Spot planting means sowing seeds or seedlings on spots at proper and recommended distance. Only the spot is prepared in the round or square form leaving the rest of the area untilled. Planting of gourds is done in this manner.

19. Growing on pandals

Growing creeping, climbing and spreading crops on pandals helps in soil erosion control as the pandals form a barrier to the rains.

20. Alternating deep rooted with shallow rooted

Crops with deep roots are grown during rainy season during which time soil erosion occurs more easily and planting shallow rooted crop during the dry season.

Concluding remarks

Top soil is the source of all our requirements in life of all living beings; soil is the vessel of water; the top soil is like

a sponge having almost fifty percent of it consists of pore spaces providing aeration to soil organisms; erosion of soil is actually erosion of human life and finally destruction of almost all forms of life from the face of the earth. Soil should be preserved by all means and preservation of soil should be every body's concern as prime environmental issue. Every environmentalist should have some basic theoretical knowledge and enough practical skills on soil conservation which is the first step for environmental conservation. When the top soil is conserved life will be preserved and cherished. No single method of soil conservation is a solution to soil erosion; it should be remembered by all that only a combination various soil conservation methods would be effective: hence a sell thought-out combination of mechanical, biological and agronomic measures have to be employed in the field for proper soil and water conservation. Initially one has to get the help of experts in various aspects mentioned in this chapter. Though mechanical erosion measures are costly without mechanical measures we cannot implement effective soil erosion control on the steep slopes, stream banks, gullies, in the rivers, streams, sides of roads and canals. However along, with mechanical measures we should always incorporate the biological and agronomic measures to improve effectiveness of the soil erosion measures adopted. Also biological and agronomic measures are income generation for the community.

Diagrams and pictures of almost all the structures of soil conservation have not been included in this chapter because abundance of diagrams and pictures are available in the internet with sufficient explanations; also with a view of bringing down the cost of printing.

Chapter-8

Water in the Ecosystem

I. Introduction

This chapter deals with some aspects of water as an important component in the ecosystem. Just like oxygen, water is essential for sustaining life on earth; life originates in water, thrives in or with water and finally merges into a mixture of moist soil or air. The relative water content (RWC) of all plant bodies range between 60-70% and of animal and human bodies varies between 70 to 76 per cent. It is an important medium for many physiological and chemical actions and reactions to take place both at the organic and inorganic level. As an ecological factor water is one of the most widely distributed compounds in the nature. It occurs in solid (ice), liquid (fresh water and sea or salt water) and gaseous (water vapour) forms in the nature. On the basis of the behavior of water in relation to temperature the thermometers are graded: at zero degree centigrade water become ice in solid form and at 100 degree centigrade water evaporates into vapour or steam. Chemically, it consists of one oxygen atom and two hydrogen atoms (H2O) in its structure, having a molecular weight of 18.016. About 71% of the earth's surface is covered with oceans without considering the water bodies on the land area.

Water is present in the capillary pores of the soil and in the molecular spaces of air in the atmosphere. It is

estimated that as much as 50,000 tones of water vapour is present in the atmosphere over 2.59 sq. Km of the earth's surface. The moisture content in a normally cultivated top soil varies between 20-30 per cent. Globally oceans, seas and bays account for 96.54 per cent of the total global water. Ice caps, glaciers, & permanent snows account for 1.74 per cent, ground water account for about 1.69 per cent, soil moisture 0.001 per cent, both saline and fresh water lakes accounts for only 1.69 per cent, the estimated moisture in the atmosphere is about 0.001 per cent, rivers account for about 0.0002 per cent, swamp water is estimated to be 0.0008 per cent and biological water in living beings account for about 0.0001 per cent; Water in liquid or ice forms are transparent to sun or artificial light which helps the flora and fauna residing in it to receive enough sunlight for all their physiological activities. Due to all these qualities and properties water has become an essential component of all living and an integral part of all non-living components of the earth-eco-system.

Water is extensively used for domestic purposes, agriculture, animal husbandry, industry and entertainment. In industry water is used as a solvent and as a catalyst; it is a standard for the concrete representation of certain physical units like litre, kilograms, calorie, melting point of ice, boiling point of water and as a standard for comparison of certain physical properties such as specific gravity, relative viscosity, used as a conveying medium for the transport of materials and disposal of wastes, as diluents or dispersive medium, a cooling agent, a cleansing medium, absorbent and distributer of heat and generation of power. Industrial hydrogen is obtained from water by electrolysis or by passing steam through a bed of hot coal. Many are the usages of water; just like oxygen water is a life sustaining component in the nature.

We consider snow as the purest natural source of water and rain comes next though it contains dissolved carbon dioxide, chlorides, sulphites, nitrates and ammonia, with organic and inorganic dust held in suspension. Water from springs and well is relatively pure whereas the sea water contain on an average 3.5 % salt.

Terrestrial life always depended on water. Not only the primitive life originated in water, but the water molecules themselves, probably, were involved in chemical reactions which resulted in the origin of life. Living organisms find both shelter and food in water and they also utilize its dissolved minerals and gases. It acts as a lubricating medium in living organisms and the flow of energy depends upon it and the cycling of nutrients in the aquatic eco-systems.

Water forms the main medium in which various physico-chemical processes of living organisms are carried out. All the vital activities of organisms such as thermoregulation, circulation, respiration and reproduction require water. We are all dependent on water in one form or another.

PROPERTIES OF WATER

Water has certain unique qualities which makes it the most suitable medium for life. Some of the most important properties are discussed here. They are grouped into physical and chemical properties.

A. Physical properties

There are mainly nine physical properties of water. They are explained here one by one.

1. Universal solvent

Water is commonly referred to as the universal solvent due its ability to dissolve such a great variety of substances in it. This property enables water to act as a transporting

medium for carrying many kinds of substances in or out through the living membranes of plants and animals. It also carries oxygen, carbon dioxide and other products of cell metabolism to various parts of the body.

2. Heat capacity

Water has great capacity to store large amount of heat and can easily conduct it from one part of an organism to other parts. It has the highest conduction capacity among liquids. This unique quality has marked effect on the heat regulations of organisms themselves and on the flora and fauna in a particular habitat.

3. Latent heat

Latent heat is the quantity of heat required to change a substance from the solid to the liquid or from liquid to the gaseous state without making any change in temperature. To convert one gram of ice at zero degree centigrade into one gram of water at zero degree centigrade 80 calories of heat is required; whereas to convert one gram of water at zero degree to 100°C it requires 100 degree centigrade and to convert one gram water at 100 degree centigrade to steam at 100 degree centigrade 540 calories of heat is needed. Thus the total requirement of heat to convert one gram of ice to one gram of steam would be 80+100+540 = 720 calories. This shows how much heat can be stored by one gram of water in the form of ice as it becomes steam.

4. Freezing point

When water at zero degree centigrade becomes ice it must give up large amounts of heat to reach its freezing point. In addition to higher freezing point there is a restricted movement of water in oceans and lakes. Therefore freezing of water or ice formation takes place only at the surface of

all water bodies; even in the small ponds the bottom layers of water rarely freeze. Therefore most of organism in the water can live and move around at the bottom layers of any water body.

5. Surface tension

Surface tension of water is defined as the lateral attraction amongst the molecules of water by which they are held together. Water has the highest surface tension of all common substances except mercury. This property of water has many ecological influences and affects the movement of water into and through the organisms. It also helps in the formation of vacuoles, pseudopodia and water drops in the cells.

6. Viscosity

Water possesses high viscosity which enables it to protect the aquatic animals and plants against mechanical disturbances. It also helps the planktonic animals to float on the surface without the aid of any swimming organs.

7. Transparency

Penetration of light is possible because of the transparent nature of water. The longer heat waves are stopped near the surface. Shorter waves with more energy penetrate and move successively farther. The ultra-violet rays go beyond 10 metre. As the depth of the water increases, the penetration of light decreases. The zone up to which light penetrates is called as photic zone, below this zone there is complete darkness and organisms which require light cannot live there. Suspended dust particles, solids and phytoplankton greatly affect the transparency of water and obstruct the passage of light. This affects the productivity of the ecosystem.

8. Density

At the sea level the pure water reaches its greatest density at 4°C and becomes lighter both above and below this temperature. Water at 4°C is heavier and sinks to bottom while cooler water (below 4°C) raises towards the surface of water and at the freezing point (O°C) forms an ice layer on the surface.

9. Pressure

At sea level pressure is taken as one atmosphere (760 mm of mercury). It increases with increase in depth of water. For every 100 metre increase in depth there is a corresponding increase in pressure by one atmosphere. Organisms normally inhabiting on the floor of the deep sea areas, at the depth of 10,500 metre are exposed to pressure of one tone per square cm. This pressure brings about a number of changes in the shape and size of different fishes and other living beings in deep sea or at various depths in sea or deep lakes.

B. Chemical properties

Water is a highly stable substance and is readily formed from its elements. In the presence of a little sulphuric acid it may be easily electrolyzed, decomposing into two volumes of hydrogen gas for every volume of oxygen. But by weight oxygen is eight times heavier than the hydrogen. It is involved in many chemical reactions as given below.

1. A water molecule consists of one oxygen atom and two hydrogen atoms

2. Water reacts with highly reactive metals such as sodium, potassium, and calcium to form the hydroxides of the metal and to liberate hydrogen.

3. At higher temperatures water acts with less active

metals such as zinc and iron to form oxides of metal and to release hydrogen.

4. Steam reduces the halogens with the liberation of oxygen ($2Cl_2 + 2H_{20}$ -> 4 HCl + O_2)" With some elements disproportionation takes place ($3S + 2H_2O$ -> $S0_2 + 2H_2S$).

5. Oxides or hydrated oxides react with water to form hydroxides which are basic, acidic or amphoteric depending on the positive element in the periodic table.

6. Neutralization is the reaction of a base with an acid to form a salt and water (NaOH + HCI = NaCI + H_2O).

7. Hydrolysis takes place when the salt of a weak base or a weak acid or both is dissolved in water. The chlorides and sulphides of many on the elements that are not strongly metallic are often completely hydrolyzed (PCI + $3H_20$ = H_3PO_3 + 3HCI, $Al_2S_3 + 6H_20$ -> $2Al(OH_3) + 3H_2S$).

8. Metallic nitrites and hydrides are decomposed by water to give NH_3 and H_2 respectively and the hydroxide of the metal. Metallic carbides yield hydrocarbons (CaC_2 + $2H_20$ -> $Ca(OH)_2$ + $C2H_2$).

9. Organic esters such as fats and oils are hydrolyzed by water to yield alcohol and the acid. Because of its small size the water molecule can fit into many ionic crystal lattices, yielding hydrates ($NaHPO_4.2H_2O$, Na2HPO$_4$. 7H20, NaH-$PO_{4.}$ $12H_2O$ etc.).

10. Salinity is caused by different salts (ions) such as sodium, potassium, calcium, magnesium, chloride, sulphate, phosphates, carbonates, bicarbonates, nitrates etc.

Many marine organisms have evolved special physiological mechanisms of excreting salts and maintaining their body tissue and fluids at low salt concentrations. The same mechanism is adopted by several plants that grow in salt affected soils.

Some marine fishes secrete salts through their gills. Sharks retain high salt concentrations and have body fluid concentrations are more similar to sea water. Many marine reptiles, birds and mammals have special renal or glandular system for excreting salts. Marine turtles and many marine birds secrete salts through their lachrymal gland. Animals which can tolerate only narrow fluctuations in saline of water are termed stenohaline (eg. spider crab, Maia etc.) while those which can withstand wider ranges are termed euryhaline (eg. mytilus, aplysia etc.). There are certain animals which are both stenohaline eryhaline in their life-cycles (eg. anguilla, salmon etc.).

STRUCTURE OF WATER

In the vapour phase a water molecule is in the form of an isosceles triangle with an apex angle of 104.5 degree. Each hydrogen atom is 0.96 angstrom distant from the oxygen atom and bound to it by a covalent bond. Ordinary ice has an open hexagonal structure with a hole in the middle through which light can pass. Hence ice looks transparent. Each oxygen atom is surrounded tetrahedrally by four other oxygen atoms and is connected to them by hydrogen bonds with the hydrogen atoms of two of the four bonds a distance of 1.00 angstrom from the central oxygen atom and with the hydrogen atoms of the other two bonds at a distance 1.76 angstrom from this atom. When ice melts about 15% of the hydrogen bonds break allowing the water molecules to pack closer together. As the temperature of the liquid is increased, more hydrogen bonds are broken down.

Hard and Soft Water

Water containing soluble salts of calcium and magnesium, such as chlorides, sulphates and bicarbonates,

is called as hard water, when these salts are absent the water is referred to as soft water. The hardness of water can be further of two types, namely temporary hardness and permanent hardness. Temporary hardness is due to the presence of calcium bicarbonate or magnesium bicarbonate. On boiling temporary hard water becomes soft due to the conversion of calcium or magnesium bicarbonates into insoluble carbonates. Permanent hardness of water is due to the presence of chlorides or sulphates of calcium and magnesium. This hardness cannot be removed by simple boiling, but requires some chemical treatments.

Composition of Natural Waters

The knowledge of various ions present in different natural waters, such as sea water, freshwater, salt water of lakes etc. is necessary for the ecological studies regarding effect of water on plants and animals and water conservation. The concentration of some of the commonly present ions in different kinds of waters is as follows.

Table 1 Composition of some natural waters (g/l)

Sl. No	Water	Na+	K+	Ca++	Mg++	Cl -	SO4-	CO3	Total (gm/ lit)
1	Soft	0.016	-	0.010	-	0.019	0.007	0.002	0.065
2	Hard	0.021	0.016	0.065	0.014	0.041	0.05	0.119	0.30
3	Sea	10.56	0.30	0.40	1.27	18.98	2.65	0.71	34.85

From table 1 it is clear that the amount of each of the common ions is more in sea water than in typical fresh-water for example it contains about 463 times more chloride ions than in hard water. Hard water contains more Ca++ and CO_3^{--} ions than soft freshwater.

EFFECT OF WATER IN DIFFERENT HABITATS

Based on the concentration, water habitats can be divided into terrestrial and aquatic environments. All living organisms are subjected to either scarcity or abundance of water in these two environments. However every organism requires a minimum amount of water to be maintained in the body for preserving its life. For example during starvation a man may lose 40 per cent of his body weight including half of the proteins and nearly all glycogen and yet without serious danger, but a loss of mere 10% of the water from his body will result in serious consequences. If 20 % of the water is lost death is certain. Maintenance of proper water balance between internal environment (body fluids) of an organism and external environment (medium surrounding the organism) is called as osmo-regulation. The effects of water on aquatic, amphibious and terrestrial environment are discussed here.

A. Aquatic environment

Sea, estuaries, rivers, lakes, ponds etc. are the common types of aquatic environment. At the outset it looks that there is abundance of water and the organisms living in an aquatic environment may not have any problem for water. But reality is different from what we think. All the organisms living in the aquatic medium have to struggle hard for water conservation and to maintain a suitable water balance between the fluid in their bodies and the environment. Because of the osmotic pressure created due to the difference in the concentration of body fluids and the aquatic medium in which it lives.

If the osmotic pressure inside the organism is same as the outside then it is easy to maintain the water balance. But if the osmotic pressure is high inside the body then water from outside will enter into the body of the organism.

In the same way if the osmotic pressure is high outside the body then water from the body will rush out. In both cases the problem will be how to maintain the water balance suitable to an organism. For example in the marine ecosystem since the osmotic pressure of sea water is high the fishes tend to lose body water whereas in the fresh water the osmotic pressure is less and the water tends to penetrate into the body of the fish. However the problem of water regulation differs from one aquatic organism to another. This single factor alone can affect the distribution of fishes and determine the ability of the fishes to live either in freshwater or in salt water.

B. Amphibious ecosystem

Life originated in water; but later on many of the aquatic animals and plants succeeded to come out of the water. The constant problem they faced was how to feed and respire without getting dried up. Hence they started to live partially in the aquatic ecosystem and partially in the terrestrial ecosystem. They are called amphibians. They can survive in both air and water environment. At intervals they re-enter the water or damp places to keep their skins moist which is necessary for respiration. However some species of organisms require water only for the reproduction and the remaining part of the life cycle they are well suited to the terrestrial environment.

If the water dries up the amphibians can move on the land and can migrate to other bodies of water. Some animals undergo physiological changes to cope up with the changing environmental situations. For example, certain fishes in India can live in wet grass for as long as 60 hours, Some animals burrow in the mud and remain in the dormant condition during dry periods. African lungfish (Protopterus) constructs special mud cocoon and

remains inside the cocoon during the period of drought. It also secretes an impervious sheath around its body which prevents the loss of water from the tissues. Certain invertebrates such as protozoans, sponges, bryozoans and crustaceans, overcome adverse conditions by producing spores, persistent eggs or cysts. Similarly, water plants produce seeds. Another extreme case of adaptation to meet the water problem is the spreading up of the development of an organism when water is available for short periods. For example Daphnia reproduces quickly by parthenogenesis when water is available. The young individuals, after maturity, also reproduce by parthenogenesis to build up a large population in short period.

C. Terrestrial system

The terrestrial environment is very much varied and water problem on the land is very often acute. The terrestrial organisms have to struggle to secure and retain sufficient amount of water. Such modifications include food habits, impervious integument, internal lungs or tracheal system, dry excretions, suspended animation, humidity control, burrowing and nocturnal habits, migration, emigration etc. For example the mountain goats satisfy their water requirements from their food. Carnivores get water supply from the blood of their prey, still some desert animals live upon their water of metabolism. Presence of an impermeable covering over the body such as skin of birds and mammals, chitinous exoskeleton of insects, mucous secretion in mollusks etc. is the first and foremost adaptation to avoid excessive loss of water.

The tracheal system of the terrestrial system is adapted to water saving for the benefit of the animals. Excretion of concentrated and relatively dry nitrogenous and faecal material is another method used by the terrestrial animals

to save the water. Some insects dispose their nitrogenous waste as solid uric acid. Many animals burrow deep into the soil in order to avoid water loss due to heat in upper layers of soil. Many animals are active at night and remain in their protective niches during the day. Many birds and mammals of arid regions migrate when water becomes scarce. In desert animals water reservoirs are present in their body to counteract the water shortage.

WATER CYCLES IN THE ECOSYSTEM

Water as an important ecological factor is in constant circulation at various levels in the ecosystem which is in a broad sense called Water cycle. The water go through a continuous cyclic process of going in and coming out of almost all the living and nonliving beings in the ecosystem such as soil, air, microorganisms, plants, animals and human beings. Through this process all the living beings receive and give out water. Through the incoming of the water into their body they receive the nutrients and water and by the outgoing of the water from their body they give away the waste that is formed in their body.

Between the ingestion and the excretion of the water by the organisms there is a period of holding the water in the body of the organism. During this period a number of functions such as thermoregulation, maintenance of water balance and osmotic pressure in the body, transport of nutrients to different organs of the body, production of enzymes and hormones for digestion and absorption, respiration, cell division, reproduction and other physico-chemical changes in the body.

The water cycle in the body of any organism is taking place in a continuous manner. This means that the organisms are receiving and giving out water either periodically or

continuously. However there are a lot of variations in this regard between one organism to another and one species to another. It also varies with the situations under which the organisms live. Fishes in fresh water will be constantly in the condition of receiving .water from outside whereas the fishes in the sea are a constant situation of losing water from their body. Most of the terrestrial animals ingest and excrete water periodically and hence they have some sort of storage place of water or body waste in their body. For example in the higher animals they have large intestine for retaining solid waste and urinary bladder for retaining liquid waste till they are excreted.

Similar water cycles are taking place at the levels of plants and micro organisms. Plants absorb water from the soil and atmosphere for their needs and transfer it into the atmosphere. In plants the ingestion and excretion of water is mostly taking place in a continuous manner unlike the terrestrial animals.

Water cycle is also taking place in a great way through the nonliving components of the ecosystem such as soil and air. Soil is the biggest vessel in which water is stored, cycled and recycled. Similarly the air also contains a lot of water which is cycled and recycled continuously. Probably the greatest mass of water cycle is taking place in the ecosystem between air and soil through the process of evaporation of water from the land (vegetation included) and ocean into-the air and by condensation of water-vapour in the air into rain, snow, dew and hailstones to fall again onto the land from where again it is evaporated into the atmosphere. This greatest ecological water cycle is the basis and source of all other water cycles that are taking place in numerous living beings (micro and macro organisms included) in the ecosystem or the nature.

In the soil the water is constantly in the movement on the surface in the form of streams, rivers and surface runoff. Whereas within the soil the water is moving in the form of seepage, percolation, streams, and channels. There are under- ground currents flowing in all directions within the earth. The geologists tell us that there are even rivers flowing underneath the dry land or even across a desert.

In the soil based on the force of adhesion and cohesion there are different types of water: gravitational water, capillary water, hygroscopic water, bound water and water vapour. The gravitational water is that part of the water in the soil which is under the influence of the gravitational force of the earth. The water under percolation movements and mass flow to the lower levels from the higher levels are examples of the gravitational water. The capillary water is that which is maintained in the capillary pores of the soil and which is capable of resisting the gravitational force. The water that is mostly absorbed by the plants is this form of water. However the capillary water is retained at forces varying from one atmosphere to 15 atmospheres depending on the type of capillaries micro or macro. Water held at high force to the soil particles cannot be absorbed by the plants and hence it is unavailable to the plants. The bound or combined water is that which is existing as part of a compound as part of the clay particle which can be seen only through an electron microscope. They can be separated only by bringing about chemical or structural changes of the compound. The gaseous form of water or the water vapour is a free water which is not under the influence of any force and is capable of free movement as long as it is in the gaseous state. All these types of water are in constant motion performing millions and millions of water cycles at the micro level in the soil.

Concluding remarks

A human being can be alive without food for about three to four weeks but cannot survive without water more than three days showing the essentiality of water in life. This unique characteristic of water controls the lives of not only of aquatic but also of terrestrial communities of all living beings. The fact that a greater amount of water exists mostly in liquid form on the earth and in all living beings, is itself something special and purposeful: seventy one percent of the earth's surface area is covered with water and also all the living beings consists of water around 70-80 per cent. Water is the medium through which all living beings carry out all their life functions like digestion of food, absorption of nutrients into the body, circulation of blood by which oxygen and nutrients are circulated throughout the body, expulsion of wastes from the body in the form of sweat, urine and excretion. Without water no life can survive on earth. Even at the inorganic level too, all actions and reactions are taking place in the presence of moisture. Many of the non-biological physical and chemical actions and reactions are taking place or are facilitated by water both in the living and non-living beings. Water has the greatest density at 4°C and it becomes less dense as it warms or cools above or below 4° temperature, a feature of immense ecological importance. It has the tremendous capacity to store heat with very small rise in the temperature. All these unique qualities of water play many important roles in the earth eco-system especially in sustaining the life on earth. Hence water management has assumed the most important involvement of man in the nature.

Rain is the primary source of water for all living beings on the land. Rain is received in pockets of land areas called watershed. "Watershed" is always defined with reference to

a drainage point on a river or stream which drains water from a specific geographical area. It is a combination of the old concepts of "catchment area" and "Command area" with reference to big dams. Remove the big dams and consider both catchment and command areas together with reference to a point in the river that drains all the water from a particular geographical area. Instead of a single big dam in a watershed there will be many small dams, anicuts, gully checks, check dams, diversion canals, ponds of different sizes, farm ponds, common or private reservoirs, roof water collection tanks, underground or overhead tanks etc.

Such water collection structures may have perennial or temporary water collections with or without fisheries and aquaculture components in it and for domestic and irrigation usages etc. The whole water shed will be scattered with many of the above mentioned water conservation structures. Lesser the rainfall more should be water conservation and storage structures in a water shed whereas greater the rainfall more should be the drainage structures.

Management of water in a watershed area is termed watershed management which is considered to be the best form of management of water in a specific geographical area. It is a collective effort of people living in watershed to control the flow of water through a watershed in such a way that water is made available to every human and every other living being. There are separate chapters on "Watershed management" and "Soil and Water Conservation Techniques". In short and to conclude this section we can say that try to impound as much water as possible in rain scarcity areas so that water scarcity can be overcome and to go for fisheries and aquaculture practices

in high rainfall areas. Build as many water conservation structures as possible in less rainfall areas whereas in high rainfall areas give more importance to drainage of excess water without eroding the land and soil.

Chapter-9

Management of the Most Intimate Human Environment

Introduction

We can consider our eco-system at various levels like one's house and its immediate environment, the land area surrounding the house, agricultural land, the village to which we belong to, the block, the district, state, country, the whole earth, the solar system, the Milky Way and the whole universe etc. At present our environmental concern is only up to the earth level. But the starting point of all types of environmental management is one's own body the environment of one's own inner self.

According to almost all cultures and beliefs, our "self" is something that resides within our bodies and is operative in one's body for the number of years we live. But we all know that the number of years we live and operate depends mostly on the way we manage our bodies and minds which are also influenced by the physical and mental traits inherited from generations of our ancestors. However even if one's inherited physical and mental qualities are of poor or below average, still one can through his/her personal efforts with a rational management of one's own body and training of his own mind he/she can erase or overcome his/her inherited negative physical or mental traits. This chapter deals with management of one's own body and mind so that

he/she has a healthy and active long life both physically and mentally.

It is a known fact that the health of parents has a telling effect upon the future generation as is clear from the genetic transmission of characters both genotypic and phenotypic. That is another reason that we should care for our body the most intimate environment of our lives. There are many aspects in the care of our bodies; among them proper nutrition is the most important: as the inputs so will be the outputs. In a world of food industry aiming primarily for money making, taste has overtaken many times in its importance over nutrition consideration. Poor nutrition of one of the parent not only affects the individual but also the future generations: medical and genetic science has already proved the transmission of genetic qualities or defects to the progenies. The increased incidence of genetic and physiological defects and deficiencies are certainly linked to the nutrition of parents of several generations back. This is much more becoming a reality in the present increasing tendency of increased junk food consumption.

The previous chapters dealt with various aspects of the management of each of the 10 components and their subcomponents. For example management of different types of soil, different types of water or moisture level or management of the slope, different levels of concentration air, light and heat etc. What is perhaps left is the management of humans themselves: each one managing his own body by himself from the environment point of view. It boils down to the question of how to manage one's body and life in a healthy way. Because even if you create the best of the environment if your body is not maintained properly/ healthy then there is no use of all other management practices in your life and environment. If you are very sick

and suffering either physically or mentally then even the best aspects of the external environment will not be of any use.

Among all the components in the eco-system the humans are the centre and master of the eco-system; they are able to control all other components in the eco-system. To do this role well he should be well, both in body and mind. **But the health of the mind depends on the body; hence his body itself is his most intimate environment.**

BODY: OUR INTIMATE ENVIRONMENT

For every human being his own body is his/her intimate environment. Human body is a very complex living and operating machine. It is good to have some ideas of the human body to understand the management of our intimate environment.

A. Basic Body Structure and Organization

We can think of the basic structure and functional organization of the human body as a pyramid or hierarchical arrangement in which the lowest level of organization (the foundation) consists of cells and chemicals. Organs and organ systems represent the highest levels of the body's organization as given in Figure 1. which conveys the idea how the body functions and the basic structure is arranged. All these structures and their functions are solely guided by the various nutrients which are to be supplied by the various food items. The nutrients are: Water, different types of Carbohydrates, proteins made up of 20 amino acids, 14 Vitamins and about 30 Minerals. All these are essential and available only through the various food items called, grains, pulses, over 100 different types of vegetables. Water is not digested but acts as facilitator of all bodily functions.

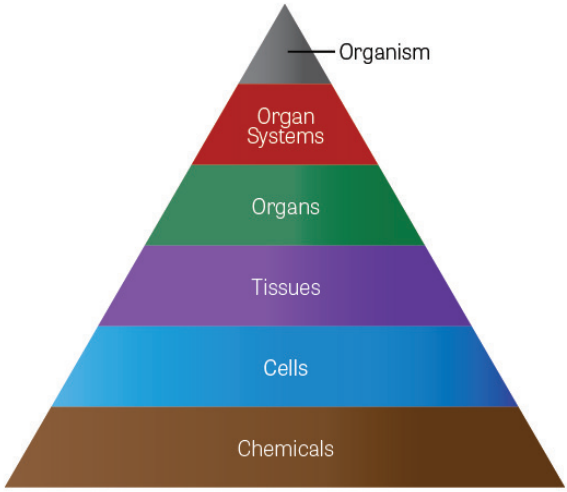


Figure 1. Pyramid represents a hierarchical organization of human body components
(Image Source: NLM)

B. Organization of Human Body

Simplified definitions of the various levels of organization within the body are the following:

1. Organ system: a group of organs that contribute to specific functions within the body. Examples include: Gastrointestinal system, Nervous system, circulatory system etc. they are eleven in number.

2. Organ: a group of tissues precisely arranged so that they can work together to perform specific functions. Examples include: heart, lungs, kidney, arteries, veins, red blood cells, white corpuscles, platelets, plasma etc. in circulatory system. Similarly there are organs in all other ten organ systems.

3. Tissue: a group of cells with similar structure and

function. There are only four types of tissues: Epithelial, Connective, Muscle, Nerve etc. every organ consists of specific tissues having different structure and functions.

4. **Cell**: the smallest living units in the body. Examples include: Hepatocyte, Neuron. All tissues consists of cells having specific functions; liver cells produce bile, kidney cells are able to separate unwanted minerals and water called urine, pancreatic cells produce insulin etc.

5. Chemicals: ions (cations or anions), or atoms or molecules that are the building blocks of all or any matter. Examples include: oxygen, protein consisting of 20 amino-acids, vitamins, enzymes, hormones and electro-magnetic waves flashing criss-cross all over the body.

Any organism will have functions at various levels: at the chemical level, cell level, tissues level, organs level, systems level and finally at the whole organism level. Animation videos are plenty in the internet showing various physiological functions taking place at all these levels in the human body.

C. Organ Systems of the Human Body

The human body consists of eleven organ systems, each of which contains several specific organs. An organ is a unique anatomic structure consisting of groups of tissues that work in concert to perform specific functions. Table 1 includes the structures and functions of these eleven organ systems.

Table 1. Structures and Functions of Human organs

Organ System	Functions	Organs
1) Integumentary	• Barrier to invading organisms and chemicals • Temperature control	• Skin • Hair • Subcutaneous tissue
2) Skeletal	• Supports and moves body • Protects internal organs • Mineral storage • Blood formation	• Bones • Cartilage • Ligaments • Bone marrow
3) Muscular	• Locomotion • Heat production	• Muscles • Tendons
4) Nervous	• Coordinates activities of other organ systems • Responds to sensations	• Brain • Spinal cord • Nerves • Eyes • Ears
5) Endocrine	• Regulates body functions by chemicals *(hormones)*	• Pituitary gland • Parathyroid gland • Thyroid gland • Adrenal gland • Thymus • Pancreas • Gonads

6) Cardiovascular	• Transports oxygen and nutrients • to tissues • Removes waste products	• Heart • Blood • Blood vessels
7) Lymphatic	• Returns tissue fluid to blood • Defends against foreign organisms	• Spleen • Lymph nodes • Thymus • Lymphatic vessels
8) Respiratory	• Oxygen/carbon dioxide exchange	• Lungs • Trachea • Larynx • Nasal cavities • Pharynx
9) Digestive	• Processes foods • Absorption of nutrients into body	• Stomach • Intestinal tract • Liver • Pancreas • Esophagus • Salivary glands
10) Urinary	• Elimination of wastes • Regulates pH and volume of blood	• Kidneys • Urinary bladder • Urethra
11) Reproductive	• Produces germ cells *(eggs and sperm)* • Environment for growth of fetus *(female)*	• Ovaries • Uterus • Mammary glands • Testes • Prostate gland • External genitalia

D. Functioning of the Organs

Human body is complex living and active machine. As we can see in the above table 1 there are about two dozen functions that are carried out by 48 major organs and 11 systems in a human body. Each organ will have specialized organ cells to carry out their specific function. To carry out each function specific type of enzymes and hormones are involved. An **enzyme** is a highly selective catalyst that greatly accelerates both the rate and specificity of metabolic reactions. A **hormone**, on the other hand, is a chemical released by a cell or a gland in one part of the body that sends out messages that affect cells in other parts of the organism. For example **Sucrase** and **isomaltase** are involved in the digestion of sugar and starches. **Sucrase** is the intestinal enzyme that aids in the breakdown of **sucrose** (**table sugar**) into glucose and **fructose**, which are used by the body as fuel. **Isomaltase** is one of the several enzymes that help digest starches. Thus to carry out numerous body functions by 48 organs, many enzymes and hormones are needed. Our bodies naturally produce both digestive and metabolic **enzymes**, as they are needed. Lactose the main carbohydrate in the **milk** is a molecule and has to be broken down (hydrolyzed) into its two individual sugars (glucose and galactose) before absorption. Lactose is broken down by the enzyme lactase that is secreted by the intestinal cells. "**Enzymes** are protein chemicals, which carry a vital energy factor needed for every chemical action, and reaction that occurs in our **body**.

As on now science has discovered approximately 1300 different **enzymes** found in the **human** cell. The **human body** secretes and circulates some 50 different **hormones**. A wide variety of these chemical substances are produced by endocrine cells, most of which are in glands. The **hormones** then enter the blood system to circulate

throughout the **body** and activate target cells. While many parts of the body make hormones, the major glands that make up the endocrine system are the: hypothalamus, pituitary, thyroid, parathyroids, adrenals, pineal body, the ovaries and the testes"- refer internet. **For the production and utilization of numerous enzymes and hormones human body needs about 14 vitamins including Vitamin D2 and 30 minerals.** Hence the most important aspect of the management of each one's intimate environment is to provide proper nutrients through the proper and balanced intake of food according to one's age, sex and work. This necessitates us to have basic knowledge of the nutrients and the food intake.

ESSENTIAL NUTRIENTS FOR YOUR BODY

The essential nutrients required for our body are the following.

1. Energy Food/Starch/Carbohydrate: They are a many types of carbohydrate molecules for providing energy for carrying out all the bodily and mental functions. Hence they are also called energy food. Among the food items which provide starch or carbohydrates are: cereals like wheat, rice, oats and barley and millets maize, jowar, bajra, ragi or finger millet, kodo, kutki, etc., and tubers like potato, tapioca, sweet potato, various types of yams, and sugar crops like sugar cane, sugar beet etc. Among these except sugar all other crops or food items can replace one with any other food item. It is not necessary that we have to eat only rice or wheat or maize or any of the millets or tubers. **Eating a mixture of the starch/carbohydrate food items is one form of food consumption. We should train our taste and food habit into a regular consumption of all types of carbohydrate supplying food items. Never say no to any of the carbohydrate supplying food items.**

The average estimated energy and protein requirements

as estimated by Dr. C. Gopalan under Indian Council Medical Research (ICMR-1981) is given in Table 2 which is indicative of the energy requirements for various categories of people.

Table 2: Daily energy, protein and other nutrient requirements for Indians**

(1)	(2)	(3)	(4)	(5)
Sl. No	Group	Particulars	Calories/ Energy	Proteins (gm)
1	Man	Sedentary work	2400	55
		Moderate work	2800	55
		Heavy work	3900	55
2	Woman	Sedentary work	1900	45
		Moderate work	2200	45
		Heavy work	3000	45
		Pregnancy (second half of pregnancy)	+ 300	+10
		Lactation (up to 1 yr)	+ 700	+ 20
3	Infants	0-6 months	120/kg	2.3-1.8 kg
4	Children	1 yr	1200	17
		2 yrs	1200	18
		3 yrs	1200	20
		4-6 yrs	1500	22
		7-9 yrs	1800	33
		10-12 yrs	2100	41
5	Adolescents	13-15 yrs Boys	2500	55
		Girls	2200	50
		16-18 yrs Boys	3000	60
		Girls	2200	50

**Recommended Dietary Intake for an Indian, Nutritive Value of Indian Food stuffs, ICMR, 1981.

2. Protein: for the growth and maintenance of body parts: All types of pulses, meats, fishes and other aquatic animals, nuts, eggs, milk and milk products etc. The average protein requirement was as given in table1 column 5.

3. Fat: for the supply of energy, fatty acids: avocados, tofu, nuts, seeds, fish, peanut butter, boiled soybean, flaxseed oil, cheese, dark chocolate and eggs

4. Vitamins: Vitamins refer to a group of organic compounds which are essential for normal growth and nutrition and are required in small quantities in the diet. Vitamins are biologically important. Although a micronutrient, it enhances the metabolism of macronutrients like proteins, carbohydrates and fats. Vitamins are also required for growth in children, formation of hormones, blood cells, tissues and bones and most importantly for brain growth. Vitamins cannot be synthesized or produced by the human body, thus, our diet must contain vitamins. They are: 1. Vitamin A, or Retinol, 2. Vitamin B1, or Thiamin, 3. Vitamin B2, or Riboflavin, 4. Vitamin B3, or Niacin, 5. Vitamin B5 or Pantothenic Acid, 6. Vitamin B6, or Pyridoxine, 7. Vitamin B7, or Biotin, 8. Vitamin B9, or Folic Acid (Folate), 9. Vitamin B12, or Cobalamin, 10. Vitamin C, 11. Vitamin D1, 12. Vitamin D2, 13. Vitamin E, 14. Vitamin K. They are divided into two groups: **Fat soluble vitamins**– A, D1,D2, E and K, and **Water soluble vitamins** – Vitamin B1, B2, B3, B5, B6, B12, C, Folic acid and Biotin. Some years ago Vit D2 was not known; similarly after some years we may discover some other vitamins too. The point is that there a number of vitamins which are essentially required for our bodily optimum growth and functions. Only then our intellect and mind will function well.

5. Minerals: So far studies have shown that about 30 minerals involved in physiological and mental functions.

They are in alphabetical order: 01.Boron, 02.Calcium, 03.Cesium, 04.Chlorine, 05.Chromium, 06.Cobalt, 07.Copper, 08.Fluorine, 09.Gallium, 10.Germanium, 11.Gold, 12.Iodine, 13.Iron, 14.Lithium, 15.Magnesium, 16.Manganese, 17.Molybdenum, 18.Nickel, 19.Potassium, 20.Phosphorus, 21.Rubidium, 22.Silver, 23.Sodium, 24.Sulphur, 25.Selenium, 26.Silicon, 27.Strontium, 28.Tin, 29.Vanadium, 30.Zinc. From the quantity requirement of view they are divided into macro and micro elements. Comparatively some of them are required in greater quantity and are called **Macro** minerals which include 1. calcium, 2. chlorine, 3. magnesium, 4. phosphorus, 5. potassium, 6. sodium, and 7. sulfur. Among the rest some are considered **Micro** elements and the rest are called **Trace** minerals meaning they are present at low levels **in the body** or required in smaller amounts **in the** human and animals diet. However they are all **essential in human growth and development.** If any one of them is missing several bodily functions can be hampered. Only their quantities are different but their essentiality is same.

6. Water: to facilitate all physiological and mental functions water is very essential.

So far we have seen what are the essential nutrient requirements for our intimate environment called human body or each one's body? Now we have to see what the food items and their estimated daily quantities required for the growth and maintenance? That is called a balanced diet.

Balanced diet for humans

Nutrition science wing of Indian Council Medical Research (ICMR) initiated a research lead by Dr. C. Gopalan on the nutrition requirement of Indian people and came out with a small book titled "Recommended Dietary Intake

for an Indian, Nutritive Value of Indian Food stuffs, ICMR, 1981. The recommended quantities of different food items required for various class of population according to sex, age and the type of work as given in table 3.

Table 3: Balanced vegetarian diet for various categories of people (gm/day) (ICMR,1981)

Sl. No	Food items for Balanced vegetarian Diet	Adult man gm/day			Adult woman gm/day			Children gm/day		gm/day	
										Boys	Girls
		Sede-ntary work	Mode-rate work	Heavy work	Sede-ntary work	Mode-rate work	Heavy work	1-3 yrs	4-6 yrs	10-12yrs	10-12yrs
Column Nos		1	2	3	4	5	6	7	8	9	10
1	Cereals	460	520	670	410	440	575	175	270	420	380
2	Pulses	40	50	60	40	45	50	35	35	45	45
3	Oil & fat	40	45	65	20	25	40	15	25	40	35
4	Sugar/jaggary	30	35	55	20	20	40	30	40	45	45
5	Leafy vegetables	40	40	40	100	100	50	40	50	50	50
6	Pods and immature fruit vegetables	60	70	80	40	40	100	20	30	50	50
7	Root vegetable	50	60	80	50	50	60	10	20	30	30
8	Milk & products	150	200	250	100	150	200	300	250	250	250

**Recommended Dietary Intake for an Indian, Nutritive Value of Indian Food stuffs, ICMR, 1981.

To purchase and to cook the daily food items according to the requirements of the six members of the families of hard working or moderately working or sedentary working, we need to estimate the **per-head-per-sex-per-work-per-family requirements of each food item.** This is obtained by totaling the individual requirements of each food item under each work-category and averaging by the family number six (6) as given in table 4. Since the poor are the most hard-working lot, we shall re-arrange the order in the third table as **"Hard working, Medium working and Sedentary working".**

Table 4: Average estimated requirements of food items for various working categories of people (gm per-head-per-day in a family of six members)

Sl No	Food Items	Per day/Per head (g) Requirement in a Hard working Family of six	Per day/Per head (g) Requirement in a Medium working Family of six	Per day/Per head (g) Requirement in a Sedentary working Family of six
1	Cereal/millets	415.00	367.50	352.50
2	Pulses	45.00	42.50	40.00
3	Oil & fat	36.60	30.80	29.20
4	Sugar	42.50	35.80	35.00
5	Leafy vegetables	46.60	55.00	55.00
6	Pods and immature fruit vegetables	55.00	43.30	41.60
7	Root vegetables	38.30	33.30	31.60
8	Milk	250.00	233.30	216.60

1. The average per head for hard working family is estimated by averaging the values of columns 3, 6, 7, 8, 9 & 10 in table 3.

2. The average per head for medium working family is estimated by averaging the values of columns 2, 5, 7, 8, 9 & 10 in table 3.

3. The average per head for sedentary working family is estimated by averaging the values of columns 1, 4, 7, 8, 9 & 10 in table 3.

4. The food items usually supplied through PDS (Public Distribution System) is highlighted.

Practical applications

Measurements of food items in the process of purchasing and preparation of each food item for cooking, serving and eating cannot be done so exact to the amounts given in table 3 or 4. The average **cumulative loss** at different levels of purchasing, storing, taking out each day's amounts of each item for cooking, serving and eating is estimated to be between 20-30 per cent. In all families there are some domestic animals to be fed also. Often there will be one or two guests also to be fed. Taking all these into consideration the average minimum estimated and rounded up requirements of food items per-head per day in the three types working families is given in table No 5.

Table 5: Rounded up average requirements of food items per head per day in a family of six members of heavy, moderate and sedentary working families.

Sl No	Food Items	Per day/Per head Requirement for Hard working Family (g)	Per day/Per head Requirement for Medium working Family(g)	Per day/Per head Requirement for Sedentary working Family (g)
1	Cereal/millets	500.00	400.00	350.00
2	Pulses	50.00	50.00	50.00
3	Oil & fat	50.00	50.00	50.00
4	Sugar	50.00	50.00	50.00
5	Leafy vegetables	50.00	50.00	50.00
6	Pods and immature fruit vegetables	50.00	50.00	50.00
7	Root vegetables	50.00	50.00	50.00
8	Milk	250.00	250.00	250.00

NB. Remember that according to ICMR (1981) as given in table No.3, the heavy working man's requirement per day is 670 gm and of the woman's is 575 gm per day and that of the children of four age and sex groups are: 175, 270, 420 and 380 gm per day. The medium and sedentary working families also will be consuming in effect the same amount of the food items because they will be consuming more of processed food items which when processed uses more or equal amount of food items compared to the hard working families.

Therefore the estimated requirements of various types of food items per head per day and per head per month are given in table 6. In the actual situations people always have to purchase a little more than the exact amount of the requirements of various items in their daily life.

Table 6: Average requirements of food items per head per day and per head per month in a family of six members in hard working, medium working and heavy working.

Sl. No	Food Items	Requirements for Hard working Family		Requirements for Medium working Family		Requirement for Sedentary working Family	
		Per day Per head (g)	Per month per head (Kg)	Per day Per head (g)	Per month per head (Kg)	Per day per head (g)	Per month per head (Kg)
1	Cereal/millets	500.00	15.0	450.00	13.5	350.00	10.5
2	Pulses	50.00	1.5	50.00	1.5	50.00	1.5
3	Oil & fat	50.00	1.5	50.00	1.5	50.00	1.5
4	Sugar	50.00	1.5	50.00	1.5	50.00	1.5
5	Leafy vegetables	50.00	1.5	50.00	1.5	50.00	1.5
6	Pods and immature fruit vegetables	50.00	1.5	50.00	1.5	50.00	1.5
7	Root vegetables	50.00	1.5	50.00	1.5	50.00	1.5
8	Milk	250.00	7.5	250.00	7.5	250.00	7.5

NB. 1. *There are about 30-40 types of edible leafy vegetables of which at least a dozen are available always in the market and it is always good to mix two or three at a time*

2. *There are about 30-40 types of edible pods and immature fruit vegetables of which at least a dozen are available always in the market and it is always good to mix two or three at a time*

3. *There are about 30-40 types of edible root vegetables of which at least a dozen are available always in the market and it is always good to mix two or three at a time*

4. *The cooked form of these three types of vegetables should be at least half the amount of the meal. To save fuel, time and effort it can be cooked in together like various forms of mixed vegetable like the South Indian Sambar and Aviyal or any other form.*

Looking at table No 6 we can say that we have a clear idea of the estimated amount of various food items that we should consume every day. we know how much rice/wheat flower/maize/jowar/bajra/ragi/tuber crops like tapioca or yams and the dal/pulses for a family of six for a meal or for the whole day; similarly we can measure 250 gm or milliliter of milk or the quantity of sugar for any one or for the whole family; but how to weigh or measure the 50 gram of each type of vegetables? Of course it is better to have a small portable balance weighing up to one kilogram in the kitchen so that we can weigh everything to the most appropriate amount of each items according to the number of persons for whom we are cooking. But if you don't have such a balance this problem can also be solved easily: 50 gm serving of each vegetable item represents a heaped handful each or one serving spoonful each of the separately cooked three types of cooked vegetables or three handful each of the mixed vegetable preparation per person. If needed, one can have two handfuls each also, in the case of hard working people. Normally 50 gram means a average size handful. But the hand sizes are varying; hence for each person his heaped handful each would be the best way to measure out the three types of cooked vegetables. Normally when vegetables are cooked the quantity is reduced to about half the original quantity. Hence at the time of cooking prepare double the amount of the required amount to be served to each person. The different types of vegetables or in other words the quantity of three vegetables should be equal to the cooked quantity of rice or wheat or any other starch/ energy food items one eats.

Improved diet

The nutrition science has improved and improvised the diet to suit to all types of people having different

eating habits. There is also a need for catering to the non-vegetarian population or omnivorous types of people. Table 7 is an improvement of the table No 6.

Table 7: Improved and inclusive of non-veg diet per person per day and per month

Sl. No.	Food Items	Requirements for Hard working Family		Requirements for Medium working Family		Requirement for Sedentary working Family	
		Per day Per head (g)	Per month per head (Kg)	Per day Per head (g)	Per month per head (Kg)	Per day per head (g)	Per month per head (Kg)
1	Cereal/millets	500.00	15.0	450.00	13.5	350.00	10.5
2	Pulses	50.00	1.5	50.00	1.5	50.00	1.5
3	Oil & fat	50.00	1.5	50.00	1.5	50.00	1.5
4	Sugar	50.00	1.5	50.00	1.5	50.00	1.5
5	Leafy vegetables	50.00	1.5	50.00	1.5	50.00	1.5
6	Pods and immature fruit vegetables	50.00	1.5	50.00	1.5	50.00	1.5
7	Root vegetables	50.00	1.5	50.00	1.5	50.00	1.5
8	Milk	250.00	7.5	250.00	7.5	250.00	7.5
9	Mixed Vegetable salad	50.00	1.5	50.00	1.5	50.00	1.5
10	Mixed Fruit salad	50.00	1.5	50.00	1.5	50.00	1.5
11	Eggs						
12	Meat/fish	50.00	1.5	50.00	1.5	50.00	1.5
13	Spices	As per need or liking of the family members					
14	Herbal Chatney/ Pickle	As per need or liking of the family members					
15	Fuel	Depends on the type of fuel: fire wood/coal/gas etc.					

NB. 1. Thus totally 14 food items would be the ideal for an individual or for a family to make up for a balanced diet.

2. It is better and practical to cook all the three vegetables together at one time in day and serve at three times after warming up a little bit before serving. To create better and different taste frying with some spices and condiments or boiling in milk or coconut milk or in any thin soury or sweety syrup etc. Serving cooked leafy vegetables alone is not very palatable to most people. That is why it advised to cook leafy vegetables mixed with some root vegetables or pods and immature fruit vegetables. That way palatability of leafy vegetables can be improved. The taste of vegetables also can be enhanced by adding appropriate type of spices and condiments.

3. Item No 15 is included for the list to estimate the cost of fuel in the food preparation per day or per month per person or per family.

4. Thus we can easily estimate the cost of balanced died per person or per family per month or per year and accordingly adjust the expenditure with the available income.

5. There are fluctuations in food prices during the year and table No 6 will help to estimate the vegetarian or non-vegetarian cost per year.

6. These estimations will help the families to adjust the income-expenditure balance per month and per year.

7. The amounts of each food item given in table 6 will ensure balanced diet for all the people.

8. It should be noted that non-vegetarians also should consume the same amount of vegetarian foods especially the three types of vegetables. The only difference is that the non-vegetarians need not take pulses. From the nutritive point of view pulses and non-vege-items are equivalent.

9. Eggs and milk are essential food items and both vegetarians and non-vegetarians should make them as part of their diet.

10. Ideally speaking all processed food items should be avoided. But in case items like noodles, pasta, upmave, rava etc., are used, they should be enriched with different kinds of vegetables, scrambled eggs, minced or grated meat items or pulses of different types.

11. Taste and nutrition are entirely different thing; as humans we should give more importance to nutrition than taste.

12. Most of the processed foods and drinks are not true to their food standards and hence unsafe for frequent consumption of them. Both, over-eating or under-eating are harmful to health and hence both over-weight and under-weight are becoming more and more common among the present generation.

13. Make a habit of taking a bowl each of mixed vegetable and fruit salads in one's diet.

Remember the saying, "One who eats for his taste shall waste his life, whereas
One who eats for nutrients will nourish his life and the lives of future generations."

Thumb rule for weight control

In the present generation one of the most physiological problems is obesity or over-weight and under weight. One should know his optimum weight which can be easily determined following the formulae: One's optimum Weight = Height in centimeters minus 100 is one's optimum weight in kilograms: eg: height is 172 cm means he or she should have the optimum weight of 72 Kg (172-100=72). One or two kilograms could be more or less. Hence one should know his/her height in cm and his optimum weight in kilograms. Keep taking one's weight and accordingly adjust the intake of food items and the level of daily exercises. It is also good to fast once week or skip an evening meal two or three times a week.

Water intake

On an average an adult person should consume two to two and half litres of water depending on the climate and the physical exertion one is subjected to. People have a bad habit of drinking too less water. For all the physical and chemical functions that are taking place in our body water is an essential ingredient. Though water does not break down in the body it is an essential ingredient in our body and is involved in all physiological functions.

Conclusion

Dr. C. Gopalan is the ultimate guide for a balanced diet, not only for all Indians but also for anyone in the world and if we follow his basic nutritive principles the world can be saved from most of the mental and physical diseases most of which are caused by the deficiency of one or other of the above mentioned nutrients. It is a pity that people eat according to their likes and dislikes which invariably causes deficiencies of most of the nutrients. Besides the physical ailments all those who eat according to the taste alone will be imbalanced or unsteady in their emotions and have less self control. Their emotional quotient will be very low and are liable to psychological and behavioral disorders up to becoming hard core criminals and social nuisances. Therefore both for the health of BODY & MIND, a balanced diet consisting of all the food items given in table 7 are to be consumed daily. The distinction can be made as per vegetarian and non-vegetarian. However non-vegetarians should consume also all the vegetarian items whereas the vegetarians need not consume any non-vegetarian items. Eat only as much as necessary. Eat also according to the nature of work.

Chapter-10

Watershed Management

This chapter consists of two parts: 1. Watershed as an Ecological System and 2. Structuring and Management of Watersheds.

1. WATERSHED AS AN ECOLOGICAL SYSTEM

Watershed management is not only a practice but also a philosophy based on socio-economic and political justice. It is an environmentally sound and ideal approach for a community based participatory development action. Various possible concepts and perspectives on watershed management are sketched in this chapter with the intention of generating a critical thinking among those who are involved in watershed development. But ultimately all water-shed management programmes should lead to the development with justice to all humans, animals and plants of both crops and forests.

Watershed management is advocated by developmentalists as a permanent solution to the recurring droughts and floods which create a host of socio-economic problems in India. Watershed is so complex a reality that there are as many concepts as there are interpreters. But a common understanding is necessary for the effective and collective action in the planning and implementation of watershed management practices for different areas. Common understanding is necessary also because man acts as he understands. If his understanding is correct and scientific, his planning and implementation will become fruitful.

What is a Watershed?

The term watershed consists of two words: "water" and "shed". Water as we all know is a compound formed of oxygen and hydrogen. It occurs in nature mostly in three forms: solid, liquid and vapour. In watershed management water is considered mainly in the liquid form.

The word "shed" may be used as a noun or as a verb. When used as a noun it refers to an inverted roof of a shed which collects rain water and drains out through one outlet. Shed, thus means an area well marked by a boundary which receives rain water and drains out through drainages which when joined together to form a common drainage. The area of a watershed is always with reference to any point in the common drainage. Shed, when used as a verb, it means "water is shed" or "poured or showered" on an area and subsequently collected and drained out. Here shed is used as a participle. So, we can say that watershed refers to an area where rain water is shed and is collected through several or many drainages towards a common drainage point. The following figures 1,2,3&4 make the concept of watershed more clear.

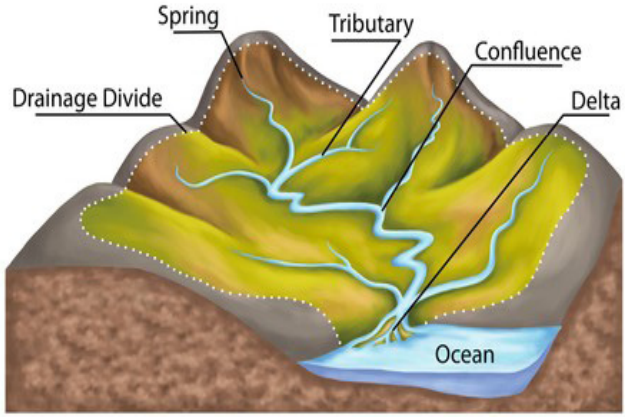


Figure 1

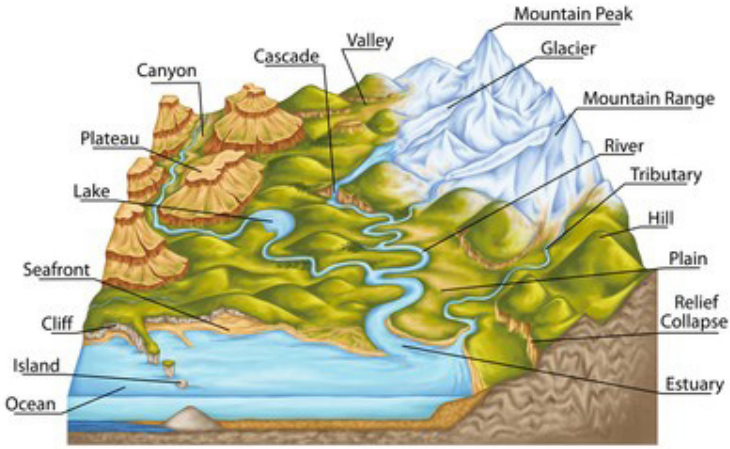


Figure 2

What's a Watershed?

- *An area of land that drains into a common body of water*

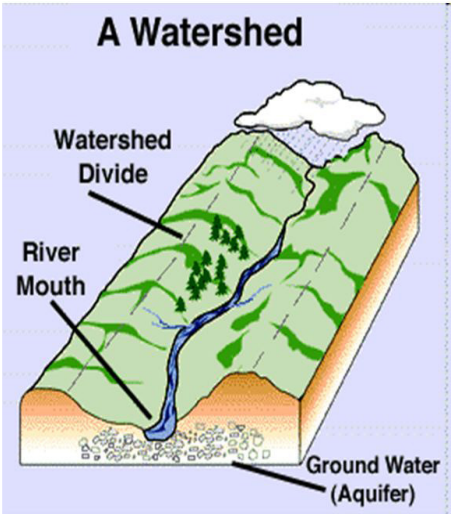


Figure 3

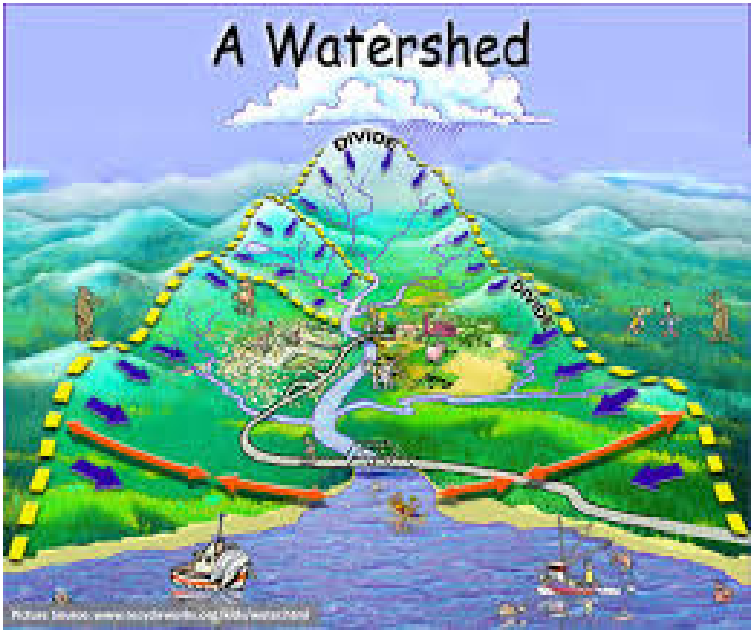


Figure 4

Characteristics of watershed

Following are the characteristics by which we can identify a watershed area. They are: 1) mouth, 2) divide, 3) upstream, 4) sub-drainages, 5) water cycles and 6) inorganic and 7) organic matter cycles. The first four are visible on the watershed while the last three are invisible. They are briefly described as follows.

1. Mouth

The term mouth here refers to the point of drainage towards which water is drained from every point in watershed through a single or numerous sub-drainages. Topographically, mouth will always be the lowest point of watershed. The point of drainage or mouth is fixed on drainage (rivers, streams or channels) according to the

convenience and the demarcation of watershed with a divide begins on the one side of the mouth and ends on the other side.

2. Divide

The boundary line of a watershed is called divide. The term divide is used because the boundary is a dividing line between two watersheds. It is an imaginary line on the top of the hills or uplands which are considered as the surrounding ridges of a watershed. Hence it is also called a line of ridge. Theoretically speaking, this line is assumed to divide even a rain drop if it falls exactly on the line of divide and will drain out half and half of rain drop into the adjacent watersheds towards their respective common drainage points. The line of divide runs through exactly the topmost points of the surrounding hills, mountains or uplands and comes back to join the other side of the mouth at the same level of the water.

3. Upstream

Upstream refers to the area that lies above the mouth and extends up to the divide. This is the actual watershed area that receives or catches rain water and drains towards the mouth. Therefore, this area is also called catchment area. It should be kept in mind that the terms upstream and catchment area have more or less same meaning as watershed. The whole watershed area, however, ultimately slopes towards the mouth in a very intricate and labyrinthine ways of numerous sub-drainages.

4. Sub-drainages

A watershed consists of numerous sub-drainages such as small rivers, streams, channels, gullies and rills which drain' water towards the main drain/river on which the

mouth is fixed. Depending on the location of the mouth the size of the water will vary: lower the location of the mouth greater will be the size of the watershed and vice a verse. The number of drainages in a watershed depends on the size of the watershed. Small drainages become tributaries to the big drainages and big ones to still bigger drainages till all join together into the main drainage/river forming a design of a profusely branched tree or a sketch of a watershed with all its drainages looks like the veins in a leaf and the petiole as the main drainage.

5. Water cycle

Water cycle simply means cycling and recycling of water from the sky above the watershed in the form of rain into the watershed which drains the runoff and percolated water through all the tributaries in the watershed to the point of mouth at the main drain. Again the drained out water comes back into the atmosphere of watershed in the form of rain clouds to make the atmosphere at the saturated humidity level and at the lowering of pressure or temperature again fall as rain or condensation. This cyclic process is called water cycle. Whenever there is rain, as a thumb rule one-third of the rain water fallen on the surface of the watershed will evaporate back into the air; one-third will percolate into the soil and one-third will flow out as surface flow through all the sub-drains to the mouth of the watershed during the rain or immediately after the rain. But during the rest of the time the percolated water will also be drained out through all the drains slowly keeping all the drains in the watershed alive. Again water evaporates from the sea or from all water bodies in and around the watershed in reference and comes down as rain when the atmosphere is saturated enough to cause rain; this process of evaporation, condensation, rainfall and draining process

takes place again and again (in cycles) depending on the climate of the place. All the drainages, small and big together, maintain the water cycle on the watershed.

6. Inorganic matter cycle

All the elements in the periodic table are called inorganic elements and compounds. Even water is an inorganic compound. All of them are present in the nature in the form of solid, liquid or gaseous forms and cycles and recycles through soil, water, air, light, heat, microbes, plants, animals and humans in many inorganic forms. Hence water shed is a system of inorganic matter cycle.

7. Organic matter cycle

Organic simply means most of the same inorganic elements are related to or being part of any organism or part of any living system. For example carbon in charcoal is inorganic but when it is part of the carbohydrate formed during photosynthesis it becomes organic. Since carbon is the most common element in any living being any carbon compound is called as organic compounds: people say all carbon containing compounds are organic compounds. Similarly sulphur, phosphorus, calcium, etc. (about 30 elements/minerals) become part of the enzymes and hormones of living organisms; they are then called organic compounds. When they cycled through soil, water, air, light, heat, microbes, plants, animals and humans, the organic matter cycle takes place.

Watershed as a System

A system means a complex unit having various interrelated components which have their own functions within the system. They are so complex that each component and its functions can be considered separately depending on

the aspect or component one wants to emphasize. We can view watershed as a (1) geographical system, (2) physical system, (3) inorganic system, (4) water cycle system, (5) organic matter system, (6) organic matter cycle system, (7) combination of water and organic matter cycle, (8) medium of cycles, (9) ecosystem, (10) flora centered system, (11) fauna-centered system, (12) homo centered system, (13) economic system, (14) social system, (15) political system, and (16) integrated economic and socio-political system etc.

Different concepts of watershed are developed based on these aspects. However, these aspects cannot be separated from one another. But for greater clarity in understanding they are discussed separately at the risk of being repetitive. The concepts are enumerated in the order of the evolutionary process from the geographical to the integrated economic and socio-political system. This implies focusing of all the watershed development activities towards the evolution and consolidation of a watershed into an integrated economic and socio-political system. Watershed as a system has no meaning in its existence unless it is developed into a political system. Political system here means a group of people who depend on a watershed, have a self-determining, self-rule system and are free from any form of exploitation. But political system cannot be sustainable unless it has a social and economic basis. Socio-ethnic and cultural factors consolidate or disintegrate a political system. However, the economic self-sufficiency is the foundation for a vibrant social system and stable political system. The successive stages in the evolutionary developmental process in which economic self-sufficiency form the basis of social stability and a stable society gives rise to a stable political system.

However, an economic-socio-political system should

have a scientific basis. Economic stability of watershed depends on the sound management of the natural resources of a watershed. Hence watershed needs to be studied from its various resource components enumerated earlier. One can look at this list from a progressive and evolutionary-chain-reaction point of view or from the dependency chain. Here the watershed-systems are explained from the evolutionary point of view. Because, the stages of development are also, going through an evolutionary process. The various aspects enumerated are described here.

1. Geographical system

Watershed at the first sight is a definite geographical area which receives drained out rain water. Watershed is a big surface drainage system. The magnitude of the watershed is determined by the elevation of point of drainage: lower the drainage point, greater will be the area of watershed and the higher the elevation of drainage point, smaller will be the watershed area. Obviously drainage point at sea level will comprise maximum watershed area.

Depending on the area of watershed it may be classified into micro, mini, midi, micro, macro and mega watersheds. A micro watershed is less than 100 ha, whereas the macro watershed may be thousands of hectares. The following is the usual classification of watershed based on the area.

Micro watershed> 50,000 ha
Midi watershed> 25,000 to 50,000 ha
Sub watershed--10000 to 25000 ha
Mini watershed-1000 to 10,000 ha
Milli watershed-100 to 1000 ha
Micro watershed < 100 ha
Farm watershed -On the farm

The total area of watershed may be consisting of various topographical features such as lakes, tanks, marshes, rivers, streams, plain lands, undulated land, hills, mountains, rocks, cultivated land, fallow land, grazing land, degraded land, uncultivable land, forests and residential and commercial areas.

In the area approach topographical features form the major basis of planning of a watershed. Generally, topography of watershed varies from perfectly leveled land to 90 degree slopes. Depending on the percentage of area under a specific topographical designation, we may call an area hilly, undulated, highly or medium or moderately sloppy, levelable or naturally leveled land. Hence the watershed management practices will vary with degree and nature of slopes of various topographical features in the same watershed.

A geographical approach is necessary in preserving a watershed from degradation or to restore a degraded one. This approach may be adapted even to watersheds uninhabited by people. The main purpose of the watershed management will be to conserve the soil, which result in the conservation of water and the enhancement of the regeneration of the vegetative cover. This approach is specifically useful to restore degraded uninhabited lands and deserting or desert areas.

2. Physical system

A watershed has not only an area but it has other dimensions such as height and depth with reference to the surface. It has a space or air volume vertically above the watershed area. Similarly, it has a depth dimension comprising of the earth volume vertically below the watershed area.

a. Air volume

The sky is the limit of the air volume above the watershed. The air volume or space receives moisture and retains it in the form of relative humidity. Relative humidity varies with temperature and pressure. Higher the temperature and pressure greater will be vapor content in the air. The rainfall in a place is influenced by the relative humidity, pressure and temperature of the air volume above it. The movement of air over the water changes constantly. The speed of the movement may vary from zero to several hundred kilometers per hour.

Temperature influences the watershed. A temperature varying between 15° to 35°C will be optimum range for watershed. Above or below this temperature plays a negative effect on the plants and animals in the watershed.

Air volume consisting of 79% nitrogen, 20% oxygen, 0.4% carbon dioxide and other gases (0.6%) is the optimum composition for a watershed. Any change in this composition can affect the watershed directly or indirectly. In many areas air pollution has become a major concern.

b. Earth volume

In the absolute sense the center of the earth is the limit of the depth of any watershed. However from practical point of view the water table or up to bed rock is considered as the depth of watershed. The volume of earth consists of minerals in the form of rocks and soil, moisture, hibernating animals (frogs, scorpions, snakes, lizards) plant roots and micro-organisms. The parent material of rocks and soil will have bearing on the watershed. Accordingly, one finds too much calcium, mica, iron, phosphorus, sulphur, manganese, sodium etc. more or less in the soil.

The soil is the actual crust of the earth and varies from

few centimeters to a meter or two in depth. The main feature of this soil is that it contains organic matter in the form of humus or living organisms. The organisms may be micro as well as macro. The top soil contains more organic matter while the bottom soil may have less or no organic matter.

Rocks, stones, gravels, coarse sand, fine sand, silt and clay are the mineral matters in the macro form; whereas, at the elemental form, practically all the known elements are present in the soil. Soil is like a sponge and there are air spaces between soil particles. These are called pore spaces which may be bigger (macro pores) or small (micro pores). Strictly speaking pore space is the total surface area of all the soil particles. These pore spaces harbor moisture, humus and micro organisms. The soil quality depends on the texture and structure of the soil particles.

The texture of the soil refers to the size of the soil particles which may be rocks, stones, gravel, coarse sand, fine sand, salt or clay. The structure of the soil refers to the arrangement of the soil particles. Water table is the level of water below the surface of the earth. The water table in a watershed may be very low or very high or fluctuate between these two according to season. It is measured vertically below the surface of the earth.

The present, level, movement and the quantity of water in the soil depends on various factors such as soil particle size, climate, seasons, level of water table and rainfall. The soil in a watershed receives water from the air volume above it though there may be underground sources from adjacent watersheds.

Physically watershed can be defined as a combined volume of air and soil which receives water and drains out through a common drainage.

The management practices of a watershed should be adopted according to the humidity, temperature, air movement, air composition, soil depth, parent material, texture and structure of soil particles, organic matter contents, pore spaces, and the water table.

Thus, in an area with high humidity and rainfall watershed management will mainly consists in conservation of soil and drainage of excess of water without damage to the watershed. For this, properly designed and laid out drainages are necessary. In a dry and arid area the emphasis will be on moisture conservation. More of mechanical and biological measures are resorted to this. Areas with high wind velocity, soil loss through wind has to be minimized. For this windbreaks and vegetative covers are established. In an area where the sun-shine is too hot, the key aspect in watershed management will be to provide vegetative cover to the land. If the soil is too shallow (less than one foot deep) the primary concern in the watershed management is to increase depth of the soil by repeated ploughing, harrowing and incorporation of organic matter. In sandy and sandy loam soil watershed management will be focused towards incorporation of the organic matter and clay particles into the soil. If it is clay soil, sand and organic materials may be added to make it loamy. In area where soil particles are gravelly, addition of silt or clay and organic matter should be emphasized. In places where the water table is high, drainage becomes the key water management practice. Thus the pattern of watershed management varies with many factors.

3. Inorganic chemical system

Watershed is a complex system of chemical elements and their interactions. The elements are present in the watershed volume in solid, liquid and gaseous forms. These

chemical elements, in the presence of each other, and under the influence of physical factors such as moisture, pressure, heat and light are in constant changes (different chemical reactions) are taking place in different forms (solid, liquid and gases). Depending on those various factors certain chemical reactions may be favoured more than the others and consequently the chemical nature of the soil will be affected by them. For example under highly hot climate watershed areas having high water table can encourage high rate of evaporation leaving the salt on the surface of the soil. Depending on the type of salts the soil may turn out to be saline, alkaline or sodic. But if the rainfall is high and leaching rate is higher the soil becomes acidic. The anion and cation exchange capacity and the pH of the soil, depends on various types of inorganic compounds present in the soil.

Innumerable inorganic reactions are constantly taking place in the watershed volume. Hence watershed can be defined as a volume of inorganic materials which receives and drains out water through a common drainage.

Watershed management should take into consideration the chemical nature of mineral material of the soil: whether acidic, alkaline, sodic, calcareousness or saline. In areas with high acidic soil, the watershed management practices should focus on, besides other things, correction of acidic soils. Similarly, in areas of saline or alkaline soils corrective measures are introduced along with other watershed management practices. In the same way calcarious and gypsiferous soils are also treated with corrective measures in the watershed management system.

4. Water cycle system

A watershed receives rain water and drains out and again receives and again drains it out. Such a process in

the watershed is called water cycle. In water cycle, water evaporates from ocean and other water bodies into air volume, where it condenses to form rain which moves through and over the surface of the earth volume. The frequency of water cycle through the soil volume of watershed varies from continuous to a very short duration of less than an hour. It is through the process of water cycle that water is made available to every nonliving things and living beings. But in order to make water available sufficiently to every thing all the time, a watershed should have continuous water cycling irrespective of the frequency of the rainfall. The aim of the watershed management is to make the process of drainage slow enough to maintain the continuity of water cycle and establish a balance between the quantities of water received and drained during any given period of time. In other words the period of drainage of certain quantity of water received is lengthened to such an extent that it overlaps the period of reception of the same quantity of water into the watershed. The main source of water in watershed is rain or precipitation. However, water may be received from underground sources such as springs located in the adjacent watersheds.

5. Organic chemical system

The inorganic reactions in the watershed are only a basis for much more complex actions and reactions at the organic level. In fact, the inorganic actions and reactions are part of the organic chemical reactions. Inorganic reactions with water are the beginning of organic reactions. Inorganic reactions can take place without water, whereas all organic reactions essentially require water. Water, thus form a necessary link between organic and inorganic reactions. Through these organic reactions chemical substances such as carbohydrates, proteins, vitamins, enzymes and

hormones are produced. The most common and basic organic reaction in the nature is photosynthesis.

These organic reactions are two types: **composing types** (building up, regenerative, synthesizing) or **decomposing types** (destroying, degenerative, and disintegrating). Synthesizing types give rise to numerous compounds, whereas the same in decomposing types will break down complex organic compounds into simpler compounds or elements. These reactions take place with the help of microorganisms. Every organic change ranging from simple disintegration of a small germinating seed to ripening of a fruit is influenced by micro organisms. Without these micro organisms plant and animal life will be impossible. Basically the productivity of a watershed depends on the microbial population it is harbouring. These microbes are everywhere: in soil water and air.

Watershed management primarily consists of creating conditions suitable for organic reactions. As these reactions are named after the micro-organisms, it is absolutely necessary to increase the microbial population in the soil mainly by incorporating well decomposed organic manure every year at the rate of three kilogram per square meter area or 30 tons per hectare. Management practices such as ploughing, intercultural operations, manuring and fertilization, use of pesticides and insecticides, selection of crops and use of bio-fertilizers should be carried out in such a way that optimum microbial population is maintained. Above all moisture conservation is of prime importance for the development and maintenance of micro-organisms and organic matter in the watershed.

6. Organic matter cycle

Organic matter means materials of biological origin.

Basically all living beings such as microbes, plants, animals and men are composed of the same elements and compounds. The most common organic compounds are carbohydrates, proteins, fats, vitamins, hormones and enzymes. These compounds are active on a living organisms but disintegrate when they die and become one with the soil from which other living beings absorb and make them part of their body. These again die and disintegrate into compounds and elements which will be again absorbed by other living beings directly or indirectly. Thus the same elements and compounds are recycled through the living beings appearing in different forms in successive generations. Such a cyclic process of organic material is called organic matter cycle.

The soil in any watershed area generates and degenerates all the living beings such as microbes, weeds, crop residues, small or big animals and human beings. They take their origin, develop, reproduce and die and become one with the soil in the same watershed in successive generations. However, when soil erosion occur the organic matter along with the top soil is transported to outside and is lost to the watershed for ever. The productivity of a watershed is directly proportionate to the amount of organic matter recycled in it. Hence the second aspect of watershed management is maintenance of organic matter cycle. With reference to organic matter cycle, watershed management is the process of maintaining organic matter generation, degeneration and incorporation of it into the same watershed.

7. Combination of water and organic matter cycle

Water cycle and organic matter cycle are two processes that are taking place in watershed. However, one cannot exist without the other. In that sense they are not only complementary but essential to each other. If there is

sufficient water available in the watershed, microbes and plants will automatically grow which will lead to the generation of animal life. Finally all these will support human life. Water and organic matter are the two essential constituents of any biological organisms. Water cycle and organic matter cycle are two supportive pillars of the ecological system. They are like two sides of the same coin or two poles of the same magnet. The cyclic process of water and organic matter ensures preservation of ecological system and the existence of biological world including man.

Watershed by its geographical structure maintains the process of receiving and draining a specific amount of water just as a pond with fishes and plants can receive and drain out a specific amount of water. The fishes and plants will have fresh and sufficient water always if the pond is receiving equal amount of water as it drains out. If the drainage is more than the incoming water, the pond will dry up. If the pond is getting more water than it drains out, it will flood the pond and overflow which will wash down the fishes and plants. There should be equilibrium between inflow and outflow if the pond has to be maintained in a suitable condition for the plants and fishes. Similarly there should be equilibrium between the incoming and outgoing water in a watershed area. This does not mean an absolute equilibrium.

There is a range of critical equilibrium below which the watershed is too dry land above which it is too wet and flooded that the normal organic matter cycle in the watershed will be disrupted and life will be impossible. Drought and flood are expressions of the lower and upper ranges of water content in the watershed.

Similarly, there is an optimum range of organic matter equilibrium, below and above which life becomes difficult.

Just as water, organic matter also exists in solid, liquid and gaseous stages. There are two types of organic matter: living and non-living. The living organic matter may be microbes, plants, animals and human beings. The non-living organic materials are organic compounds such as carbohydrates, proteins, fats, vitamins, hormones and humus. There should be two kinds of equilibrium in the organic matter cycle. They are:

1. Equilibrium between living and non living matter in nature, and

2. Equilibrium between microbes, plants, animals and human beings.

If the rate of regeneration of animals and human beings are greater than the rate of regeneration of plants, there will be shortage of food, fodder, fuel, fibre, timber etc. However, if plant generation is more than animal and human generation, it will lead to the well being of animals and human beings. Normally it does not affect the animals and human beings. However, if microbial generation is less than the optimum level, it will affect the growth of plants, animals and human beings. Because, the microbes are essential for plants and animals, as regenerators and degenerators.

8. Media of cycles

As already mentioned water and organic matter exists in nature in solid, liquid and gaseous form. Hence the media also have to be in the corresponding forms. However, both liquid and gaseous forms can get adjusted into a porous medium of solid particles.

Having described briefly the relationship between the state of existence of media, we come to the actual media of water and organic matter cycle. Earth and its atmosphere are the two media through which water and organic matter

are moving around. Both have immense capacity to store water and organic matter. Among these, earth may be more important as far as organic matter cycle and biological systems are concerned. In correlating water cycle and organic matter cycle with earth the top soil plays a distinctly leading role in the maintenance of most of biological system by conserving water and organic matter within itself.

In a watershed the media for water cycle and organic matter cycle are same, i.e. earth/top soil and the atmosphere just above it. All the living beings in the watershed receive water and nourishments (elements and compounds) from the soil and atmosphere.

9. Ecosystem

From above discussion, it is amply clear that whole watershed functions as a system. A system as already described is a complex unit having a number of components but all acting together to perform a common function. The major components of a watershed are the same as that of the wider ecosystem of which watershed is only a part. Ecosystem means a system of components related to living beings and in which action reactions are taking place in a cyclic and reciprocative manner. The major components of ecosystem are soil, water, air, light, heat, micro-organisms, plants, animals and human beings. Obviously, watershed is also composed of these components. Hence, watershed is a unit of ecosystem as well as part of the larger ecosystem of any geographical or administrative unit such as sub-divisions, districts, state, country, etc.

The components of the watershed as an ecosystem can be grouped into two: the living and the non-living, soil, water, air, light and heat form the non-living components of the ecosystem. Plants, animals and human beings constitute the

higher form of living components. Between these forms are the primitive life forms. They are grouped into micro flora (minute organisms with chlorophyll), micro fauna (minute uni and bi-cellular organisms) bacteria and virus. They are also called the lower forms of life and are collectively called micro-organisms. All these components act and react together ultimately to support human beings who depend on a watershed for their existence and development.

A deeper understanding of the components reveals that there is progressiveness in the existence and functions of these components. Soil, water, air, light and heat are requirements for the survival of micro-organisms, whereas plants require soil, water, air, light, heat and micro organisms. Similarly, animals also require plants for their existence. Their whole ecosystem is centered around man. The ecosystem can be considered as a pyramid: man, animals, plants, micro-organisms, organic chemicals and inorganic chemicals which are in the forms of soil, water, light, heat and air. It can also be considered as a pattern of concentric cycles beginning with humans at the centre then animals, plants, micro-organisms and the non-living materials. The outer most ring will consists of soil, water, air, light and heat.

Topographical considerations play a major role in the, planning of a watershed management. Generally the slopes of the watershed vary from perfectly leveled to 90 degree slope. Hence the method adopted for the water management will vary from place to place. Further, depending on the percentage of area under specific topography we may call an area hilly, undulated, highly sloppy, medium or moderately slope, leveled, level able or naturally leveled land. Accordingly the watershed management practices are different.

10. Flora centered system

Watershed also can be considered as a flora centered system. Flora means plants and they range from microscopic plants to the giant sequoia trees. The inorganic and organic reactions provide the necessary nutrients from the soil to the plants: The plants convert solar energy into chemical energy (starch) using these nutrients from the soil and additional nutrients from air and water. This process is called photosynthesis, the basic food manufacturing process in nature. Plants being immobile derive their nutrients only from the soil and air volume of the watershed. All the geographical, physical, inorganic and organic aspects of watershed discussed so far function as a support to plant growth. Plants generate bio-mass in nature in the form of leaves, stem, flowers, seeds, fruits, roots, tubers etc. These generated biomasses in a watershed are decomposed by micro-organisms into simpler compounds and elements which the following generations of plants absorb from the watershed volume. Thus there occurs a cyclic process of plant regeneration and degeneration in a watershed.

Therefore, watershed can be defined as a volume of plant growth with all its supportive processes and plant centered watershed ecosystem can be considered. People who give priority to the preservation of flora diversity may adopt a flora centered watershed management which consists of organizing every thing in a watershed (soil, water, air, light, heat, physical inorganic reactions) in such a way that it gives rise to maximum support to plant growth.

11. Animal centered system

As we know plants, whether domesticated or wild, support animal life. Animals are also domesticated as well as wild. Every watershed in nature harbors animal life, wild

or domesticated. Wild life sanctuaries and zoological parks are examples of wild life centered watershed; whereas, domestic animals depend on man managed-watersheds. Animal forms of dairy cows, sheep, goat, pigs, rabbits, chicken etc. which are supported by farm lands are examples of domestic animal centered watersheds.

In the evolutionary process in nature animals emerged after the plant life and they depend on them directly or indirectly for their existence. If a desert watershed is reasonably vegetated into a forest, all kinds of animals get naturally established as if the whole process was for harbouring a certain number of animals. In a watershed the same process takes place. The plants are static in a watershed whereas animals can move from one watershed to another locality. However, if proper environmental conditions are available animals prefer to remain in the same area.

Hence, watershed can be considered as a group of animals and their environmental unit which maintain the water cycle and organic matter cycle to support the animal centered eco-system.

12. Homo centered system

All the systems so far discussed function towards the evolution of man in nature. He is the crown of creation or nature. He takes control of a large number of the functions in nature. He reorganizes them and manages them to suit everything. All other things have meaning in existence so far as man gives them meaning. He is the master of everything in nature at the same time his life is influenced by the animals, plants, soil, water, light, heat and air.

Man is the end product of the millions and trillions of years of evolutionary process. The management of every thing in nature is for the benefit of man. The same

is applicable to the management of all the resources in a watershed. Everything in a watershed is managed by the man for his own benefit. Hence watershed management can be considered a homocentric system. Man depends on the watershed for all the basic things required for his existence and development.

13. Economic system

When man starts using things individually or collectively, he begins to subscribe economic values to each and everything. All the natural resources in the watershed including the human labor and services are valued and compared. Based on this value, man starts exchange of things essential both for the existence and development. Such exchanges take place based on some norms defined by the value of things in nature. This value is determined by the abundance or scarcity of things. Hence the norms of exchange and utilization of things required by man is determined by the existence of the same things in abundance or in scarcity.

Watershed, as already mentioned, provides man all the necessary things. However, different people in the watershed produce different things and are sold or bought by people within the watershed or outside. At the same time people in a watershed has to purchase things required for them and which they are unable to produce. Thus, buying and selling became a practice. Based on this, man developed the science of economics.

The watershed management is oriented towards improvement of production and economic self sufficiency. The watershed should be able to support economically the inhabiting human population. Hence various resources in the watershed are arranged and reorganized in such a way that the watershed becomes productive.

Production in watershed may be agricultural, animal products or natural resources. Some watersheds may produce more commodities than others.

14. Social system

Social unit strictly refers to a group of people in the form of a hamlet, village, town, or city. But broadly speaking, it includes their environments on which they depend. This is especially true in the case of hamlets, villages and to some extent towns.

Man derives all his basic requirements for existence and developments from his environment. This environment consists of all the components in nature (soil, water, air, light, heat, plants and animal). All the physical inorganic and organic changes in these components are the natural processes which produce man's basic requirements for existence such as food, fuel, fodder, fibre, fertilizers and money on nature. Watershed is the basic unit which is capable of producing these requirements. Similarly man also requires certain things for his development. They are family, education, friends, medical facilities, jobs, recreational facilities, road and transport facilities, communication facilities, knowledge improvements, technologies, implements, instruments and machineries, marketing facilities for various inputs and out: puts etc. To avail all these he needs money or purchasing capacity. Ultimately man's purchasing capacity comes from the land and other natural resources. Further if we analyze we can see that watershed is the unit in nature that produces all the basic requirements for a social unit (village) for their existence and development. In other words, a social unit (village) derives its social and economic needs from its watershed.

Therefore, watershed is best defined as a socio-economic

unit (village) and its environmental area on which it basically depends for the existence and development. Watershed management consists in the management of all the natural resources of a social unit to ensure the availability of all the requirements for its existence and development.

15. Political system

The socio-economic unit located in a watershed has to be a political unit with self determination if it has to develop fully. A political unit primarily is characterized by its power of self determination. True development of a social unit takes place only if it has self determining power on its social and economic life. Self determination for a group of people implies control over themselves and on the environmental area on which they are depending for their socio-economic development. It also necessarily implies their control over what they have produced in their environmental area.

Production process involves the following functions: (1) inputs (capital, land, raw material, machinery) and (2) production function (labour, management, repair and maintenance) and (3) outputs (products, storage, processing and marketing). Ultimately self determination consists in having control over these three functions. Control over these functions by the social unit is possible only if it has the knowledge about various inputs and outputs and their management. Obviously a lot of theoretical and analytical knowledge is required.

The theoretical and analytical knowledge has to be translated into productive action. Here comes the need for proper technology which means knowledge i.e. what and how to do. One cannot have control over the products if he does not have the control over the productive functions involving management of inputs and outputs.

In order to do these functions successfully, the social unit needs tools. Tools are the extension of man's talents and senses. It is through these tools that man is able to under- stand the most complex realities in the production process. Hence control over production necessarily implies possession and control of tools.

When a social unit has control over knowledge, technology and tools in the production process applied in its environmental area it has real political power. This political power is the crown of developmental process of any social unit. However, this has to be based on the fulfillment of the basic economic requirements for the existence which comes from a watershed.

Hence, politically watershed can be defined as a politically self determining social unit and its environmental area on which they are directly depending for their existence 0and development.

Watershed management thus means management of the watershed and all its resources by the people, for the people, to produce all their basic requirements for the existence and development.

V. Integrated Socio-economic-political Approach

The first idea that comes into the mind of any one in watershed management is the conservation of water in the watershed area and making it available to every living being; plants, animals and human being. Because water is basic not only to every living being but also for the proper functioning of physical, inorganic and organic systems. However, all these are supportive for the existence of a human social unit. At this level most of the individuals in the social unit will be mere labourers operating only at the socio-economic level of existence. They can go on

existing happily for generations without any development taking place just as many tribes lived in the forest for many centuries. Such units may be self sufficient at the existence level. Hence mere soil and water conservation management and enhancing plant and animal growth will not be sufficient in watershed management practice if real development aspect is included. It therefore, becomes imperative that factors contributing to the development of the people should be simultaneously established in a watershed. They are listed below.

1. Road and transport

Road and transport facilities are most essential for bringing input and moving out the outputs. Mobility is very essential for managing materials, knowledge, technology and tools. Every land holdings in the watershed should have road and transport linkage. Hence net of roads is an essential component of a watershed.

2. Educational facilities

Education both literacy and numeracy are prerequisites to development of a society. Every one in the watershed should be provided with all the facilities for at least good standard of literacy and numeracy in the watershed planning.

3. Electricity

In the modem world electricity plays a major role to make man's life comfortable and especially efficient in his work. Electricity is a pre-requisite for every one to avail the better technologies and tools.

4. Water supply

Though watershed development is creating abundance

of water in the area, for house hold purpose water should be supplied through pipes. This will save a lot of time and energy of womenfolk in the watershed.

5. Marketing

Marketing facilities for all types of consumer items and inputs for land and other natural resource management should be part of any watershed development programme. Otherwise individuals in the watershed take up such occupations and automatically become exploiters. Similarly, marketing of all the outputs from the watershed also should be organized for the benefit of the people and must not be left in the bands of few economically powerful.

6. Communication

Communication facilities such as post, telephone, telegraph playa great role in the development of the people. Watershed development plan should include creation of such facilities.

7. Medical facilities

Adequate medical facilities for cure and control of diseases provide life security to people in the watershed. Without this all other developmental efforts become a waste.

8. Recreation facilities

All work and no recreation makes a man dull. Besides the traditional facilities there should be improved recreational facilities.

9. Saving schemes and banking

Watershed development improves the economic status of the people. But it cannot be stabilized unless saving is introduced among people.

10. Consumer cooperatives

Often people are drained economically due to the high price of the food and non food consumer items. Watershed management should include this as one of the items in their planning.

11. Religious worship

Places of religious worship should be respected and maintained in the watershed development.

12. Agricultural services

In all watersheds, agriculture will be a major occupation of the people. They should be provided with extension services, exposure programmes, better seeds etc. Inputs such as seeds, fertilizers, insecticides, pesticides, machineries, sprayers, pump sets etc. should be provided on rental service to those who cannot buy them.

13. Veterinary service

Animals are part and parcel of watershed and there should be facilities for upgrading and cross breeding of cattle, preventive vaccinations feed and fodder services, etc. All the animals in the watershed should be registered and insured.

14. Drainage

One of the causes of insanitary conditions in the villages and towns is improper drainage. After water development is carried out, the need for drainage will be more. Use of drain- age water for irrigation is a best way to utilize the drainage water.

15. Insurance scheme

People in Watershed area are exposed to a number of

risks. Therefore, proper insurance schemes should be introduced into the watershed to cover all such risks.

16. Land development

Land development in the watershed is a capital intensive laborious and one time work. Farmers will not be able to bear the expenses nor do they have the labour to accomplish it. Hence land development such as terracing, leveling, drainage making in each holding should be carried out by the watershed development programme.

17. Storage

Production in a watershed area increases with improvements in watershed management. However, if adequate storage facilities are not provided the producers will be discouraged to produce any more than they can store and, therefore, cold storage facilities are necessary.

18. Processing industries

Producers in a watershed are often compelled to sell the fresh products at low price. At the same time it is possible to do primary or secondary processing at the producers level and to obtain better price for the products. Such facilities will generate additional job opportunities.

19. Population control

Every watershed has a maximum carrying capacity (ability to support people). Increase in population beyond this will upset the balance. Hence watershed development necessarily should include population control as a permanent programme.

20. Cottage industries

Often all the people may not have sufficient land to cultivate and they have to depend on other jobs for their

subsistence. Cottage industries which are able to provide sufficient jobs should be planned along with watershed management.

21. Vocational training

Along with creating job opportunities in the watershed there should be facilities for training in skills for various jobs.

22. Housing

Housing is one of the basic requirements for existence of every human being. Every one in the watershed should have a proper housing and such a scheme should be part of the watershed management.

23. Sanitation

The surrounding of the social unit should be maintained clean. People should be educated to keep the environment clean. Such educational action programme should be built into the watershed scheme.

24. Community hall

Social functions such as marriages; cultural programmes etc are part of any social unit. For this there should be a proper hall in the watershed.

25. People's organization

People should be organized into a group which discusses its problems and issues and plan out strategies to solve them. The whole social unit can also be organized into sub groups like women's group, youth, landless, scheduled castes and tribes for dealing with specific problems related to them.

26. Prevention of social evils

Social evils such as drinking, dowry, drug addiction, gambling, money lending at exorbitant rates are bottlenecks in the development of the people in a social unit. Hence, wherever such problems exist, watershed development should include measures to check these anti-social evils.

Conclusion

Watershed is not only a eco-geographical but also a socio-economic and political unit. People in this unit depend on it primarily for their existence and secondarily for their development with social justice. In a watershed development approach both these aspects should be taken into consideration. Existence without development is meaningless and development without existence is impossible. The ultimate aim of watershed management is development with justice. To attain such an aim we need to have an integrated approach in the watershed development.

Part II

II. WATERSHED STRUCTURING AND MANAGEMENT

There are three types of watersheds: 1. Catchment area and 2. Command area. 3. Integrated Watershed.

1. Catchment area: The catchment area simply means, the area where the rain fall is received and flow down through various streams, small rivers to bigger ones to the mouth of the water shed at which place a dam or an anicuts is built to store water during the rainy season and which can used during the scarcity times. We usually refer to catchment area of a dam; that means the upper areas of the dam which catches the rain water and pass on to the

mouth of the river at which point a dam is constructed to impound water.

2. Command area: This is the area where the impounded water is used for power generation or irrigation of agriculture fields or fisheries or aquaculture on the land areas where human beings are involved for agriculture and food production and areas where he builds up his villages, towns and cities and his operational places like industry, institutions, transport and airfields etc. These two sections are clear in big dams created for 1. Power generation, 2. Irrigation and aquaculture programmes. A third type of watershed is the integrated watershed which implemented in the agricultural land of a village or in several villages.

3. Integrated Watershed: In integrated watershed there is no differentiation between catchment area and command area: both catchment and command area merged with each other; these are mostly farm lands belonging to various owners but within a watershed area of standard definition: having well defined mouth, ridge line, small and medium size drainages seasonal or perennial flow, merging with a main drain where the mouth is located; the watershed area may be at different heights, having soils of various types, with a range of annual rainfall, situated within an agro-climatic region, harbouring a certain number population of humans, fauna and flora; Most of the population will be belonging to farming families and obviously most of the land area will be belonging to them though there may be some common lands like forests, barren land, grazing land or water bodies like a common constructed pond or a natural lake etc. The slope of the land may vary from zero to 90 degree. Whatever can be done in that kind of watershed will be only with consent of the people with various ideas and objectives and consensus may be very

rare. Some common programmes like check dams, anicuts, stream bunding, gully plugging, diversion channels of water supply, impounding water into private or public ponds, stream bank protection, soil and water conservation programmes, some common programmes in agriculture, animal husbandry and fisheries and aquaculture etc.

Principles and Objectives of Watershed

The principles and objectives of the integrated watershed are as shown in Fig 5, and Fig 6.

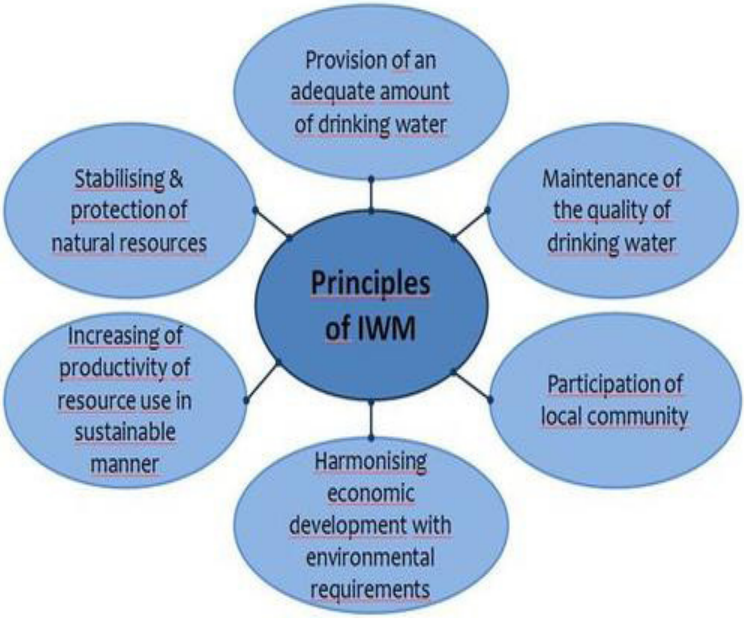


Fig 5. Principles of watershed

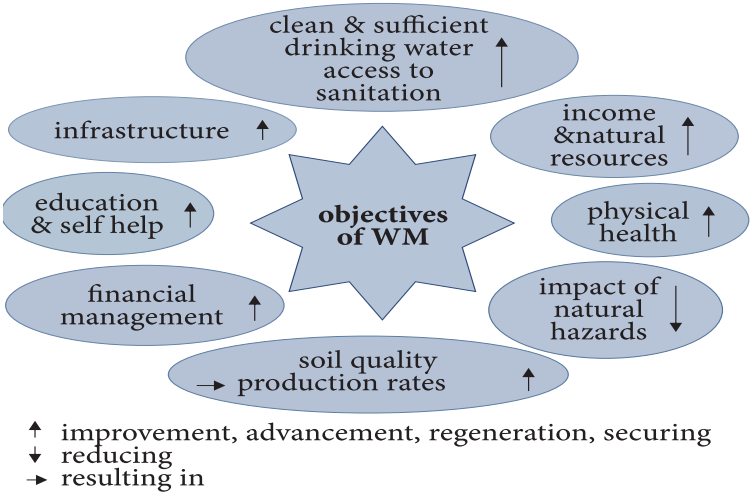


Fig 6. Objectives of watershed

In the internet there are many figures on the principles and objectives of watershed; Fig 5 & 6 are given here as examples.

Sequence of watershed planning

There are a number of sequential steps in planning for all the three types of watersheds mentioned above. The sequences of watershed planning are given in Fig. 7. They are as follows:

Fig 7: Sequence of Events in Watershed Planning

Land related: Land inventory, land capability inventory, allotment of land use to units, match conservation needs with land use involving decision of priorities to make economic decision,

Water related: water inventory, assessing erosion hazards, soil and water conservation works

Common matters: Data collection and monitoring, evaluation

Fig 7 is a model of sequence of events in planning of a natural resource and strategy management. There can be more such components depending on the different watersheds created in different locations. It ultimately boils down to two: land management for soil conservation and water management for more income generation and preservation of natural resources. It means preservation of every grain of soil and every drop of water in the watershed area and use of them to the maximum level. Preservation of

all bio-resources is a third objective; the bio-resource may natural or cultivated and there are different in different areas where watersheds are located.

Watershed Structuring and Management

In the first part we talked about a full watershed of pretty big area with reference to a big stream or a river having the dam as the mouth and with reference to the mouth a catchment and command area are demarcated and watershed management operations are done in the catchment and command areas. But in the case of groups of farmers having a small holdings together is their watershed area: meaning the area into which a certain amount of water is received through rain or other sources belongs to a number of farmers and their lands are collectively held as one watershed. It may be the case of few or more famers together having their individual properties in a contiguous manner and are within the same watershed area. In such a case all the farmers should join together to decide on the items of watershed management practices in their contiguous properties as one common watershed.

The combined or individual property area may be flat or undulated with slopes of varying degree. The rainfall may be high, normal or scarce; the soil may be deep, medium deep or shallow; soil may be fertile, medium fertile or infertile; soil type may be clayey, loamy or sandy or a mixture of all the three as is always the case will be; the vegetation may be profuse, medium or scarce. The owner or the owners (in the case of watershed management done together) of the land should have the some of these basic information.

A. Land Structuring According to the Slopes

The first step in watershed management is the structuring of the land according to the slope of the land.

Structuring is both physical and biological. The details of the structuring of the land are repeated from seventh law from chapter 6: "The Commandments and Laws of Nature". The Structuring of a water shed normally starts from the topmost part of the land area. For the convenience of the readers, slope wise land use and watershed management is repeated here with some modifications.

1. All the slopes above 33.3% (1:3 ratio of vertical to horizontal) should be placed under perennial natural forests with 100 per cent canopy coverage except those areas that are covered with large rocks and grass lands. Even the rocky areas and grass lands above 33.3% slope should be forested as much as possible. Usually such land areas will not be in the possession of individual people. However any one has a property of this slope he should never go for any land use of his own. Needless to say that all the springs in the level should be preserved though tapping of water through pipe lines may be permitted. In the forested areas create as many check dams, stream bunding, spring preservation natural forests, contour trenching without causing soil erosion, impounding of water at as many locations as possible should carried be out so that as much rain water as possible can be percolated into the soil as possible. Watershed management in the areas above 33.3% means to allowing water to sink as much water as possible into the perennial forest soil so that it will appear later in the form of springs at the lower ranges of the slope. First of all no private property should be allowed on slopes at and above 33.3 percent.

2. All the slopes ranging between 20 to 33.3% (1:3 to 1:5 vertical to horizontal) should be put under perennial crops like fruit trees, plantation crops or planted timber trees. But the springs originating in these areas should be preserved with a perennial protective cover of natural forest of 100

to 200 feet in radius around the spot the spring comes out. Terracing with supportive rock walls can be practiced. If any irrigation facilities is to be incorporated they should be well lined with cement, pre-caste cement channels, stones or tiles to prevent water loss through seepage.

3. All the lands having slopes ranging between 10 to 20 per cent (1:10 to 1:5 vertical to horizontal) slope should be contour terraced before they are used for seasonal crops. However terracing of land between 10 to 20 per cent (1:10 to 1:5 vertical to horizontal) is not economical and highly soil erosive: the question is where will the displaced soil be placed? Better to put this land under perennial crops of long duration fruit trees, perennial pulse and vegetable crops or some other forms of cultivation in which no or least soil erosion takes place. If any irrigation facilities is to be incorporated they should be well lined with cement, pre-caste cement channels, stones or tiles to prevent water loss through seepage. Maximum soil water conservation should be ensured in the planning and lay out of this area.

4. Areas between 5 to 10 per cent slopes can be used for seasonal cultivation provided leveling and terracing or other soil and water conservation practices are adopted. If any irrigation facilities is to be incorporated they should be well lined with cement, pre-caste cement channels, stones or tiles to prevent water loss through seepage. In the case of irrigated cropping land there should be well laid out irrigation and drainage channels properly built into the terracing and plotting of the seasonal cropping area. At convenient locations there should be facilities for composting the crop residues, weeds of animals refuse while they are working in the field. Structuring of the land should be done in such a way that least human labour is required as it is becoming more and more costly and scarce. Maximum soil water conservation should be ensured in the

planning and lay out of this area.

5. Land areas between 0 to 5 percent slopes are the best for extensive cultivation of seasonal crops like cereals, millets, pulses, vegetables, flowers etc. without much soil conservation measures. However, proper roads or paths to gain accession for people and machines to each plot should be ensured. Similarly a well laid out irrigation and drainage channel should be designed and fitted into the cropping area. Maximum soil water conservation should be ensured in the planning and lay out of this area.

6. Areas less than 0 degree slopes or low lying areas can be used for sugarcane or wetland paddy cultivation or any of the suitable forms of fisheries and aquaculture. It is highly advisable that any low land area should be maintained as water bodies and should never be filled in as is done in many places in India. In Bangalore, more than a dozen lakes were filled up, Chilka lake in Orissa is being reduced from all sides by the encroachers, low lying area of Kuttanad in Kerala and mangroves in many parts of West Bengal etc. are being converted to lands for commercial and residential usages. Fisheries and aquaculture is less expensive and hence more profitable per unit investment than crop farming.

Structuring of crop land with proper approach roads or paths and well laid out irrigation and drainage channels is very important and such structured land should never be divided or partitioned under the law of inheritance; because the irrigation and drainage channels and other facilities created on the field cannot be divided or partitioned. In a well structured land maximum rain water can be stored up and maximum of the drained water can be stored in non-permeable tanks for aqua-culture and for reuse for irrigation.

B. Water Management in Watershed

The second foremost programme in a watershed is to store as much water as possible for agriculture, animal husbandry and aquaculture. The source of water may be rain, surface run off, spring, stream or river. Even if there is plenty of water and apparently there is no need for stored up water, still a watershed manager should store as much water into the soil and also into as many impermeable tanks as possible for fisheries and aquaculture which is more profitable than any agriculture or animal husbandry practices.

1. Storing of rain water

As already mentioned watershed management consists mainly also in capturing and storing the rain water as much as possible in the land area either into the soil or into a storage tank. During rainfall normally about one-third of the rainfall seeps down into the soil; one-third of the rain fall will evaporate back into the atmosphere; and one-third will be lost as surface runoff. From the total rainfall of an area the runoff water can be estimated and stored into nonpermeable water tanks built below the ground level or partially below and partially above the ground or fully above the ground as the case may. Estimate the total run off during the year and the utilization during the year or season; the difference of which will the volume of the tank required in a catchment area. There can be more than one tank in a cropping a cropping land. Every time rain occurs the runoff water will be stored up in the tank which will be reused in the field during the water scarcity time.

a. Storing of infiltrated water: Another key point in watershed management is to increase the infiltration of rain water into the soil and retain them as long as possible so that the crop plants will get the moisture during the full

growing season. The soil moisture can be preserved by **deep ploughing** few times before the rainy season or during land preparation for the sowing of the crops. **Incorporation of organic manures** at the rate of 20-30 tons per hectare during the last ploughing or harrowing will increase the moisture storage capacity of the soil considerably. **Mulching** after sowing the crop will retain the moisture to a great extend. Mulching may be with any plant material or crop residue or weeds or poly-ethylene sheets. **Dust mulching** soon after harvesting by running a harrow lightly over the land to cut off the upward capillary movement of water during summer non-cropping season. When such agronomic practices are done year after year the soil moisture retention capacity will increase considerably over the years.

b. Storing of runoff water: during the rainy season there should be some nonpermeable structures like a pond, a tank of sufficient size located at the lowest part of the land area. If needed such water storage can be in more than one location. All the runoff water during the rainy season should be stored up into it for future domestic or agricultural use. If the water storage is open to air space there will be loss of stored up water through evapo-transpiration due to heat of sunlight and air movements. The best way to control the loss of water through evapo-transpiration is to cover the tank or pond permanently with a permanent roofing structure to cover the tank to preserve water in a dark or semi-dark atmosphere which situation prevents the growth of algae and other minute aquatic plants and disease causing microbes.

c. Preservation springs: If a spring is located within your land it should be preserved intact by not doing any tillage in a circle of 50 -100 ft radius with the spring as the center. This marked area should be covered with thick

vegetation of natural forest which will act as a protection to the spring. In the upper region of the spring may be dotted with moderately deep trenches and pits to increase the storage of rain water into the soil as well as to augment the spring capacity.

d. Storage of stream/river water: If a stream or a river is passing nearby the watershed area, water from them can be diverted during the rainy season to sizable nonpermeable storage tank dug into the earth and to which water from the source can be diverted and stored in for year round use. These day high grade plastic sheets are available to spread under the ponds to retain water instead of cement or concrete. Such high grade plastic sheets are will last several years during which time one can make sufficient income by fish rearing to earn enough income to spread cement or concrete at the base and side of the pond.

e. Additional use of storage tanks: The above mentioned water tanks may be used for fish and aquaculture practices for additional income besides the use of water for irrigation and domestic use. Such storage tanks are advisable even in areas there is no scarcity of water; because any such water storage tanks can be more economical as they can be used for fish and aquaculture for cost of production is much less compared to agriculture.

Construction of a storage tank of long term use is an expensive affair for a farmer. It will incur an expense beyond any ordinary farmer though in the long run it is an income generating investment. Construction of a water tank is a onetime investment which will generate regular income to the farmers and hence Government should provide grants or loans to the farmers. As already mentioned in the Laws/ Commandments of Nature capital investments should be met by the government whether to the individual farmer or for a group of farmers.

Following are some of the slides of watershed implemented in various places in India to show the variations in the implementations of watersheds.

Fig 8: Soil Erosion Control Structure

Fig 9: Construction of a Village Pond

Fig 10: gully Plugging

Fig11: Construction of a percolation tank

Fig12: Half-hazard Water Shed in a Wet Land

Fig13: Check Dam with Sections for Overflow

Fig 14: Drainage Canal in an Irrigated Field

Fig 15: Check Dam with Full Length Overflow

Fig 16: People at work in Percolation Tank Construction

Figures 11 and 14 are done more to give work for the unemployed people rather than storing water; only the rain that falls into it may be stored; there are no water sources from which water can be diverted into the ponds and hence the utility of this pond is in question. Many such works were undertaken in many parts of India as part of the watershed without any water to store for the people. Temporarily some people got the benefit of some casual jobs.

The Government of India launched watershed Programme in 1983-84 in a big way in to conserve and utilize natural resources for higher productivity of crops and more income/employment generation in addition to creating better climatic conditions. Various development programs including watershed development programmes.

Which Programmes are included in watershed development?

1. Rural Poverty Alleviation. 2. Pradhan Mantri Adarsh Gram Yojana, 3. National Panchayati Raj Day. 4. Pradhan Mantri Khanij Kshetra Kalyan Yojana. 5. Ministry of Rural Development. 6. Gram Swaraj Abhiyan. 7. Women and Child Development, 8. Scheduled Caste Welfare. It is interesting to note that there was no information on the soil and water conservation aspects. As usual all technical programmes are hijacked to social programmes and lot of time and effort is spent in discussing socio-political issues in which the people are all highly vocal and at the end of the meeting all the people become in a state of euphoria of having done something; whereas watershed development is a highly technical matter and it is only the technical people who can achieve the desired results. But there is a serious hurdle in the implementation of the watershed in India: Individual ownership of the land remains a big hurdle in the way of watershed development. Individual ownership stand against any proper implementation of soil conservation and water conservation programmes which cuts across the individual ownership of the land. Some ponds have been made in a common land where no water can be stored. The decision where to dig was taken by the community, some poor people got some days of job; after digging the pond people went away home.

There were several organizations competent technically

to implement watershed programmes in India. Several of them were dismantled and assembled into a social organization instead of strengthening them technical. Thus concrete result oriented approach was lacking.

a) Regarding people participation, the programme is ineffective especially among women and youth, nominal involvement of panchayat raj institutions and local lvel voluntary organizations in all the watersheds.

b) Training is Inadequate and hence there is lack of motivation from local organizations and the state and district level watershed committees did not function in most ofthe projects.

c) Integrated watershed approach has not been followed at the implementation level and the criteria for prioritization of watersheds are weak.

d) In the implementation process, pre-project preparation is very weak and the departments involved in the process are lacking coordination and linkages in several programmes.

e) Regarding the sustainability of the programme absence of the involvement of the stakeholders is a major drawback as the support from the respective state governments and related departments are very weak.

f) In the watershed programme, there has been a high cost menu resulting in poor sustainability. In most of the cases, location specific and low cost indigenous technologies are not adopted.

By June 2014 a national level Watershed Atlas was created in India. In this Atlas, the entire river systems of the country have been divided into 6 Water Resources Region, which have been further, divided into 35 basins and 112

catchments. These catchments have been further divided into 500 sub-catchments and 3237 watersheds.

A survey was conducted at 37 watershed locations under different agro-eco regions in India during 2001. Data were collected from primary stakeholders pertaining to physical (ground water, soil erosion, runoff reduction, etc.), biological (afforestation, cropping intensity, productivity levels of dryland crops) and socio-economic parameters (additional benefit-cost ratio, additional annuity value, etc. and additional employment and reduction in outmigration of labour, participation of farmers in watershed programmes) in watershed programme areas compared to non-watershed areas. The analysis indicated that there was an increase in all factors in watershed area villages compared to non-watershed area villages. **However, there is no significant difference among the project implementing agencies viz., National Watershed Development Programme for Rainfed Agriculture (Ministry of Agriculture), Ministry of Rural Development, with regard to reduction in soil erosion, etc.** It is also recommended that Non-Governmental Organizations may be encouraged to take up watershed programme works on their own funds only. Government of India, Indian Council of Agricultural Research and Non-Governmental Organizations, have succeeded in achieving the results in watershed development programme. Log it on to regression equations were fitted to different factors in relation to additional income per hectare, but distance to market was found to be significant but other factors were not significant. Finally it is recommended that water harvesting structures may be constructed at suitable places and it is essential to establish vegetation for optimal success of the programme.

Concluding remarks

Watershed programmes are most suitable for initiating a holistic developmental process in a democratic and equitable way. Every watershed is a unit in nature and people automatically belong to one or other watershed in which the natural organic matter and water cycles are taking place as twin process in nature. It is for the people to define their watershed and initiate watershed development process and continue to its completion and later to carry on with it with the aim of establishing an economic relationship of **production, processing and marketing** in which everyone has a role to play in it and profit from it. Any watershed begins with soil and water conservation programmes followed by various production programmes, processing of products to make them non-perishable, transport to various centers of outlets, marketing and feedback from the people and provisions for mid-term corrections and improvement. We can make a blue print for any watershed area taking into consideration the SWAT (Strengths, Weaknesses, Opportunities, and Threats) analysis or any other management dictum into which watershed management is incorporated provided everyone has an adequately profitable role to play: profitable economically, educationally, socially and politically.

Chapter-11

Planning for Watershed Management

Introduction

There are many models and formats for planning watershed management. However all of them are too technical and too much in detail to confuse any ordinary person who is associated with watershed management. To implement a watershed management programme in its entirety ten to fifteen years are needed. But most of the watershed management programmes are three to five years and the activities that can be implemented during this time is very limited and hence the planning should be according to the feasibility limitations. Hence this book aims only to give the bear minimum guidelines for the planning of watershed management programme.

Watershed management starts with survey of the land and the natural resources with the people of the watershed area. This is followed by a detailed planning of every thing one wants or needs to implement in the watershed. The survey comprises of studying the situation of the land and all the natural resources in view of making a plan for the better utilization of them and to improve the living standards of the people. All the items coming under the social, geographical, environmental, economical, political, flora and fauna related aspects can be considered in the survey for the watershed management. In other words there is, nothing that does not come under the watershed survey

which is considered in any of the other surveys. However it all depends on the types of watershed and the people who live on it.

If people are not in the watershed then there is no need for: a survey of things related to socio-economic and political aspects; If people are belonging to different economic strata and belonging to different caste groups etc. then we have to take a survey of those aspects. Or if the watershed is dry and arid area almost like a desert then we may have to include certain items related to desertification or desertification. Similarly if the watershed is the habitat of certain rare species of plants or animals then we have to take a survey of those things. Thus we can never say that one single survey form will be applicable for all the watersheds. The most important of the aims of watershed is to preserve the top soil of the area and to conserve sufficient moisture in the soil and also to impound runoff water into ponds, small or big reservoirs and other water holding structures and go for economically viable fisheries and aquaculture practices. Second important aspect of watershed is to forest perennially all the areas above 33.3% slope and to place all the areas between 15-20 per cent to 33.3 per cent slope under perennial orchards and other tree crops.

Generally the NGOs who are doing the watershed are familiar with the socio-economic and political survey and hence this booklet do not deal with those items of survey coming under socio-political aspects in detail though a short format of the same is included in this chapter.

Most of the watershed management programmes are for three to five years. Therefore it is not possible to implement all the ideas any one\or a group of people want to implement in a watershed however beautiful they may be. Watershed management is implemented in areas where

water is scarce and where the soil erosion is a problem. Resultant to the soil erosion problem is the problem of productivity, sustainability, environmental stability and ultimately the existential problem of the people inhabiting in the watershed.

Hence the objectives of watershed management programmes in the order of priority are: (1) to reclaim the eroded land (2) to, prevent further erosion of soil (3) to conserve run off rain water, (4) to increase agricultural production for food and cash (5) to establish perennial forest in all the areas above 100% slope, (6) to maintain adequate tree cover (through orchards, fuel wood plantation, fodder tree plantation in all areas with slope ranging between 30 to 100 per cent, (7) to preserve all the water sources in the watershed area if any, (8) to implement soil conservation measures in all the cultivable land bunding in land with slopes ranging from 1 to 7 per cent and terracing in land with slopes ranging from 8 to 30 per cent, (9) to maintain the carrying capacity balance (10) to maintain the ecological balance and (11) to preserve the biodiversity. These are the fundamental objectives of any watershed and all the rest is only corollary to these.

Therefore the outline of the procedure for the planning and implementation of the watershed is given in this book is strictly referring to these basic objectives. Anyone can add any number of objectives to these and enrich the watershed management programme to any level of implementation.

STEPS IN WATERSHED MANAGEMENT PLANNING

The watershed programme is usually initiated by the government officials or NGOs. They are called the Project Implementing Agencies (PIA) and if they want to take the

watershed management programme they should normally go through the steps given here. The steps given here are more like guide lines rather than steps to be followed strictly. In some places and with some people all these steps may not be needed. But with some other people there may be a need for additional steps and sub-steps. The PIA should adapt these steps to each situation and to the people they are dealing with. The following are the steps recommended but the numbering may not be the order of procedure.

1. Identification of area

The identified area may be a natural geographical watershed or social watershed (village) which may be part of a natural watershed or part of several natural watersheds. The identified area should be having problems related to water scarcity, soil erosion, agricultural and animal husbandry productivity. In watershed management we begin with finding solutions to these problems and move on to development of the people.

2. Prepare a rough plan

This is a broad plan consisting of the basics of water-shed. It will help the PIA's to present the idea of watershed and to motivate the people to take up the watershed programme in their area.

3. Contact with the people

The villagers are contacted by the PIAs through any of the conventional means and in collaboration with the village chief call for a village meeting in which the people are encouraged to talk about their problems. Carefully guide the discussion to the idea of watershed management. Prioritize their problems. Explain concretely the advantages of water-shed approach as a solution to their problems and

leave them to think it over and ask them to call back if they are interested in implementing the programme.

4. Contact again

If they do not call back make a second or third attempt to contact and get their consent. If they are not ready then better not. to go for the watershed programme in that area.

5. Watershed Committee

If they are ready ask them to form a watershed committee in which equal representation of all classes of people in the village/watershed.

6. Negotiation with the committee

Explain the details of the watershed plan, the implications, theirs and the people's responsibility and share of benefits, how the benefits should be shared among the beneficiaries etc. Take enough time to negotiate and do not start the programme until and unless the people are ready and there is consensus among the people on the programme.

7. Consent in writing

The people should express their agreement in writing.

8. Preliminary survey

After the written consent is obtained conduct a preliminary survey of the watershed using PRA techniques in which people's knowledge of the place is much taken into consideration. First of all identify activities (leading to achievement of the above mentioned objectives) leading to solution to the people most important problems in relation to watershed management and prioritize them.

9. Prepare the rough estimate of the cost

Calculate the cost of each of the possible items or activities being planned for the implementation along with the water- shed committee. Prepare a schedule of time for completing the activities. These plans and costs are only tools for the implementing agencies to conduct and guide the discussion and to lead the people into the various aspects of watershed management.

10. Clay/mud model

Prepare a clay/mud model of the watershed more or less in scale at a convenient place in the village and in proportion to all Its details of the present situation showing slopes of varying degree, plain land, submerged land, erosion, deforestation, problem soils, forest land, cultivated land, barren land, pasture land, orchards, ponds, wells, tanks, buildings, institutions etc. In preparing the model take the help of the people. Let the people see and allow them to make comments and even improvements and modifications in order to make the model an exact replica of the watershed.

11. Present the model and the plan to the people

The model will show to the people what their watershed look like with all its problems. It will give them a clear idea of the present situation of their area and the discussion that follow will naturally lead to what could be done to improve the situation. The discussion will lead to a concrete plan for the watershed development. During the discussion allow the people to interact with ideas of the implementing agencies and allow better and new ideas to emerge. The model and the plan along with its rough cost estimates of each item is presented to people by the village committee members in the presence of the NGO/govt officials (in the

village meeting) and get the consent of the people. The govt/NGO officials should observe the people's reaction and assess the degree of their eagerness. If people are not sufficiently motivated then leave the people to discuss the plan again and get their full consent.

12. Get a second written agreement

After the people got a clear idea of the implications, % expenditures, their roles, responsibilities, expected contributions etc. make a final written agreement between people, watershed committee and the PIA (Project Implementation Agency).

13. Make the detailed survey and plan

This plan is made in the form of maps with all the details of every activity and the cost is calculated. If the finance is not a constrain all the activities that are needed or planned will be included in the plan. If finance is a constrain then take up the activities on the priority basis.

14. Make another clay/mud model

By the side of the previous model make another model showing all the details of the activities to be implemented in the watershed so that people will be able to observe the same watershed before and after implementation. In preparing the second model also people should be involved.

15. Presentation of the second model and the plan

The watershed committee presents the plan with the help of the model in the presence of the PIA. Allow the people to criticize, present better and new ideas. After incorporating all the suggestions and ideas of the people make the final plan for the watershed. Ideally speaking a watershed development programme should he made

16. Final agreement

Make a final agreement with the people, the committee and the implementing agency specifying the exact works in sufficient details the amount of contribution in terms of labour, money, land and other things. The agreement also should specify the manner in which the benefits are shared among the beneficiaries.

17. Monitoring of the work

There should be good monitoring and supervising team to make sure that the implementation of the all the works are done in time and the quality of the work is maintained.

18. Periodical evaluation

During the period of implementation there should be periodical meeting of the committee, the people and the implementing agency to take stock of the situation, the progress of the work etc. At every stage make sure that the people's full cooperation is obtained and all chances of misunderstanding should be avoided.

19. Keep record

Keep a record of all the details of the work, materials stored and used for the work, labour and other people involved and various types of expenses. Such records should be made available to anyone who would like to look through.

20. Complete the work

Complete all the planned activities as per schedule and ceremoniously hand over the watershed project to the commit- tee and to the people.

SURVEYING THE WATERSHED

The following procedure is presented here as a model. This can be adapted and modified according to the circumstances and the people.

A. Preliminary survey

Walk over the whole watershed with the help of some of the villagers and get an idea of the whole area. Use the PRA techniques in the preliminary survey. Make a rough sketch and a model of the watershed. These will be used in the preliminary discussion with people.

B. Detailed survey and action plan

The information received from the PRA will help us to decide which are the areas we should go for detailed survey. During the detailed survey help of the experts and technicians should be utilized. The following are the items specially noted during the detailed survey which will take several weeks or months depending on the size of the watershed. Final result of the survey should be shown in a scale map in which all the details are shown. Sometimes more than one map may be required to show all the details. Sometimes certain parts and structures have be enlarged in separate maps.

1. Eroded areas

First of all identify the areas which are subjected to erosion. This is to achieve the first objective given above. Demarcate and number the places and note also the degree of erosion and list them in the order of decreasing intensity of erosion. According to the intensity of erosion categorize them into very severe (deep gullies), very severe (shallow gullies), severe (small gullies and rills), moderate (rill and sheet erosion), not apparent (thin sheet erosion). Decide the types of reclamation practices and structures such as check dam, gully checks, bunds, stone or brick structures, brush wood or gibbon structures etc. at each location of erosion. Decide the number of structures (give identifying numbers) and determine the dimensions (length, width and height) and construction material of each structure. Estimate the cost of each structure.

2. Categorization of the slopes and land utilization

Using two straight sticks of about 5-10 ft length, a spirit leveler and a foot ruler determine the vertical and the horizontal components of the slope at regular intervals on the contour line or whatever lines and wherever possible. Vertical/horizontal x 100 gives the percentage of the slope. Categorize the slopes into the following as given in the table 1 and note the area under each category. The table also gives an idea of the type of soil conservation measures and the possible land use pattern.

Table 1: Proposed categorization of slope for various soil conservation measures and land use pattern.

Sl. No	Range of slope %	Vertical by horizontal	Soil conservation measures*	Land usages proposed**
1	Up to 3	3/100	Field bunds	All types of crops
2	4-7	4-7/100	Contour bunds	All types of crops
3	8-10	8-10/100	Broad base terraces	All types of crops
4	11-15	11-15/100	Broad terrace	All types of crops
5	16-20	16-20/100	Broad bench terrace	All types of crops
6	21-25	21-25/100	Vegetative, Orchards	Fodder & Horticultural Trees
7	26-30	26-30/100	Vegetative, Orchards	Fodder & Horticultural Trees
8	31-50	31-50/100	Perennial forest	Planted timber trees
9	51-75	51-75/100	Perennial forest	Planted timber trees
10	76-100	76-100/100	Perennial forest	Planted timber trees
11	> 100	--	Perennial forest	Natural forest

* These recommendations are tentative and depends of climate, soil types etc.

** These recommendations are tentative and depends of climate, soil types etc.

For each category of slope at each location plan meticulously the appropriate soil conservation measures. The details of the mechanical structures (number, size, dimensions etc.) should be noted during the survey. Similarly in the case of vegetative structures also detailed planning is important. Estimate the cost of each structure. The chapter on "Soil Conservation Measures" describes all the possible soil conservation structures.

After categorizing the slopes decide the areas to be established with natural forest, areas to be planted with timber wood trees, areas to be planted with firewood trees, areas to be planted with fodder trees, areas to be planted with fruit trees, areas to be made into narrow bench terrace, areas to be made into bench terrace, areas to be made into broad bench terrace, areas to be made into broad terrace, areas to be made into broad base bench terrace, areas to be covered by contour bunds and areas to be covered by field bunds. Determine also the type and number of saplings, the length and width of the terraces, the length and size of the bunds. Estimate the cost of each of these items.

3. Forestry & tree cover areas on slopes

At least one-third area of every watershed should be under the tree cover excluding the orchards. Another aspect of the tree cover is that all the slopes above 100% or 45^0 angle should be under perennial forest and slope ranging between 30-100% should be under planted forest or orchards. Land above 30% slope should not be cultivated under seasonal crops. People in the watershed area usually do not follow these principles. It is suicidal to break these basic principles of land management. Demarcate the areas that should be under permanent forest and tree cover in the form of planted forests and orchards.

Decide what species of trees or fruit trees, what design, in how many acres and how many trees etc. and calculate the cost of establishing forestry and orchards.

4. Locate positions for water holding structures

Sunken structures, ponds, percolation tanks, wells, trenches and pits are the water holding structures in the watershed. Determine the number and dimensions of each of these structures. Give identification number to each of them and estimate the cost.

5. Locate the existing water resources

The existing water resources may be streams, rivers, springs, wells, canals etc. The best way to preserve them is to provide vegetative protection on the sides or around all these water resources. In some places the sides of these water resources should be built up with stones and cement. It is highly advisable to construct anicuts and barrages across the perennial streams. We can also construct diversions from the perennial stream leading to ponds, tanks, wells and other sunken structures. In short conserve all the run off rain water, water from the rivers, streams and springs in the watershed. Impound as much water as possible and use for fisheries and aquaculture.

6. Identify soil erosion problems in the cultivable areas

Wherever soil erosion problems are seen study the situation and decide the appropriate soil conservation measures. Determine also the dimensions of each structure and its cost.

7. Identify the uncultivable leveled land

There may be areas which are leveled and due to some problems are not cultivable. Such lands may be put under the tree plantation or any other usages.

8. Identify the problem land

Acid soils, alkali soils, saline soils, polluted soils are called the problem soils. Identify the areas and decide the appropriate measures to be adopted to reclaim the soil. Estimate also the cost of reclamation.

9. Identify the common land

The common lands may be belonging w any of the slope categories or to the plain, land. It may be a problem soil. Accordingly we should plan for the utilization of the common land and estimate the cost.

10. Identify the pastures and grazing land

If pastures and grazing lands available study the condition of them and see if there is any improvement to be done. Many of the pastures could be incorporated with fodder trees to make it two tier type of fodder production or some new and better varieties of fodder grasses could be introduced.

11. Identify submerged areas

Identify the waterlogged and submerged areas and according to the situation and the liking of the people plan for any of the aqua cultural practices. Estimate the cost also.

12. Identify perennially cropped areas

Fruit trees, tea, coffee, oil seed trees, drum stick trees, nut trees and other plantation crops are perennial trees. Determine the area under each of these types of crops, number of trees, planting design, any mixed or companion cropping etc. should be decided along with the cost factor. Include in the perennial crops food as well as cash crops. Include also the programmes for the introduction of the

new varieties of perennial crops and their management practices.

13. Identify the seasonally cropped areas

The seasonally cropped areas should be well leveled to avoid (minimize) soil erosion. Further adopt suitable agronomic practices to reduce even the sheet erosion. Include in the seasonal crops food as well as cash crops. Include also introduction of new varieties of crops and crop management practices.

14. Tree plantation

Trees can be easily planted on bunds and boundaries of plots, on the sides of the roads, canals, play grounds, residential areas, institutional areas etc. Identify such locations, the type of trees, number etc. Estimate the cost of tree plantation.

15. Animal husbandry programme

Identify the types of animals that can be promoted in the watershed and decide how many families how many animals can be given to each family etc. Estimate the cost benefit-analysis of the different types and units of animals.

16. Biomass recycling

In most of the Indian soil the organic matter content is very low, Plan for a systematic generation: and incorporation of all the biomass into the cropping land Compost. all the animal and crop. wastes and incorporate them into the fields. Practice mulching and green manuring whenever possible.

17. Infta-strubtural facilities

Take note of the' need; presence or absence of the infrastructural, facilities such as road; electricity, transport,

communication, schooIs, health centers, banks, water supply, drainage, sanitation, recreation, consumer stores,: marketing, storage, processing, vocational training, library, community hall etc. and accordingly decide the facilities to be introduced into the watershed.

18. Social aspects

Besides the soil and water conservation social and economic development programmes such as population control, self help and saving schemes, processing of agricultural and animal husbandry products, processing of horticultural products, handicrafts and other rural employment generation should be included in the watershed plan.

19. Maintenance of the carrying capacity balance

Carrying capacity balance is the equilibrium between the demand for food and other things and the production supply of the same in an area. Ultimately the demand and production should be determined in terms of money. For this first all determine the demand for the food and other things in terms of cash. Then see whether the watershed is producing the same in sufficient amount in terms of money. If the demand and production arc in equilibrium then the carrying capacity balance is maintained. If not adjustment has to be made either increasing the production or reducing demands. Sometimes reducing the demand means population control of the area. The demand also can be met by imports.

20. Maintenance of bio-diversity

Efforts should be made to preserve all the flora and fauna of the watershed. This is already achieved to some extend if one third of the area or all the slopes above 30% is kept under forest cover. Besides this positive eff'orts should

be made to collect, replant and grow all the trees, shrubs, bushes, herbs and grasses of the place.

OUTLINE OF THE WATERSHED PROJECT PLAN

The readers are reminded strongly again that this is only an outline of a plan of a watershed management project to be used as a guide line by anyone who wants to prepare a watershed management project. Anyone who uses this outline should be free to adapt and modify it according to the need of the place and situation. The following are the items. that are normally coming under the project plan.

Title: Watershed Management Plan of (name of the village)

Address: ----------

Legal holder ----------

Implementing agency----------

Consulted agents:----------

Anyother:----------

Introduction: Write an introduction to the project giving need and scope for the project and any other relevant factors.

Section I General Description & Socio-Economic Survey

A General description

In this section provide a general description of the project area coming under the watershed management as per details given under the following subheadings. This general description can be written after the preliminary survey and the PRA exercise with the people of the village.

1. Location

The location of the watershed is specified by naming the Village, Block, Tehsil, District, State, Longitude, Latitude, approach road, important landmarks etc. (include an indexed map).

2. Features of watershed

The main features are area, elevation, shape, topography, mountainous, hilly, plane, undulated, degraded, dry, vegetated, rocky etc.

3. Climate

The following climatic factors are considered while surveying the watershed area.

a. Rainfall

From the nearby weather recording station we should get the average rainfall of the past 50 years and monthly average rainfall of at least past ten years or at least few years.

b. Temperature

From the same station we should get the monthly maximum and minimum temperature of the past ten years or at least few years.

c. Humidity

From the same source get the weekly average humidity of the past ten years or at least few years.

d. Bright sunshine hours

From the same station, get the weekly average sunshine hours of the past ten years or at least few years.

e. Wind velocity and direction

Monthly data is collected for the last ten years.

f. Evapo-transpiration rate

Evaporation refers to the amount of water evaporated from surface of the water in a pan and the transpiration refers to the amount of water transpired from the surface of the green leaves of grass covered area. Both are measured in cm or inch.

g. Others:

Cyclone, torrents, frost, hailstorm, dew, hot winds, soil moisture variation etc. are to be recorded.

4. Drainage

Record drained, not drained, partially drained areas.

5. Natural vegetation

Record types of vegetation, coverage, scanty, rich, medium etc.

6. Agriculture & Horticulture

Record types, levels, intensive, extensive, etc.

7. Animal population

Record types, general health, maintenance, level of animal husbandry practices.

8. Human population

Caste, rich, poor, farmers, business people, educated, tribal, scheduled castes etc.

9. Land holdings

Record percentages of landless, marginal, small, medium and big farmers, their, ownership,

10. Institutional financing facilities

Make a record of private money lenders, cooperative, bankers, etc.

11. Means of communication

Record types, accessibility, post, telegraph, phone, fax, E-mail etc.

12. Marketing facilities

Note the presence of market for the disposal of farm and forest products.

13. External influence

Record the effect of mining, dams, industries, railways, high ways, wild animal sanctuaries etc.

B. Checklist for Socio-Economic Survey

1. Name: the village group, number of villages in the group,

2. Number of households: farmers, non-farmers, total,

3. Population: nos., male, female over 14 years, children under 14 years total number,

4. Occupation: main and subsidiary,

5. Living conditions: in numbers of household goods, fair, poor,

6. Number or households: by farm size <0.5 ha, 0.5-1.00 ha, 1.0-2.0 ha, 2.0-3.0ha, >3.0 ha,

7. Ownership: farm-owner, tenant, share-cropper, etc.,

8. Fuel source: in per cent collected, fuel forest, oil and others,

9. Fodder supplies: sources forest, farm forest, self-owned grazing lands or grass lands,

10. Livestock: nos., draft cattle, water buffalo, dairy cattle, pigs, chicken and others,

11. Water supply: nos., sanitary piped. village wells individual : wells, river and others,

12. Quality of road connections: in village, village to fields, village to village, village to markets, village to service center, etc.,

13. Schools and education: location and distance primary village school, district school, middle school, illiterate adults %,

14. Home and cottage industry: nos., bag machine, rope machine, spinning and weaving tools, wood-carving and others,

15. Power tools: nos., tiller, duster, sprayer, duster-sprayer, thresher, 4-wheel tractor, etc.,

16. Market: name, distance, type of market village, town etc.,

17. Service centers: name, distance, types etc.,

18. Main supply center: name, distance etc.,

19. Public facilities: nos., electricity, telephone, post office, bank, medical center, hospital, midwife, community center, public yard, public garden, etc.,

20. Home gardens: nos., & size for vegetables, fruit trees, fuel wood, etc.,

21. Village cooperatives: consumer, producer, marketing, etc.,

22. Village warehouse capacity: square meters, cubic meters,

23. Village store: nos., cooperative, individual,

24. Home improvement: nos., houses, kitchen, fence,

farmyard, store room, farm buildings such as firewood storage, cattle shed, tobacco curing shed, silkworm shed, etc.,

25. Organizations: farm improvement club, home improvement club, youth club, village association, credit union, etc"

26. Indebtedness: to government, money lenders, etc.,

27. Other improvements: according to locality and

28. Priority of improvements: as given by village community.

PRESENT LAND USE PATTERN

After the general description a detailed study of the present land use pattern is given in the project. The following subheading will serve as guide lines writing this section. The present land use can be written after the preliminary survey and the PRA exercise with the people of the place.

A. Agriculture: the data collected on agriculture may be filled in a tabular form.

1. Rain fed area: area, crops raised, yields, rotations, management practices,

2. Irrigated area: area, crops raised, yields, rotations, management practices,

B. Forest: details about the forest are collected under the following subheadings.

1. Type of forest: type of forests may be tropical ever green, tropical moist deciduous, tropical dry deciduous, tropical thorn forest, tropical dry ever green, littoral and swamp, sub-tropical broad leaved, subtropical pine, subtropical dry ever green, mountain wet temperate, Himalayan temperate and alpine forests.

2. Age & nature: whether old or new (rough estimate in years) whether planted or natural.

3. Level of management: good, fair, poor,

4. Pure or mixed: rough estimate of various species in percentages.

5. Canopy density: top canopy, middle canopy, undergrowth, ground cover by the canopy in percentages or as good, medium, poor etc.

6. Litter: good, medium or poor.

7. Climbers & parasites: whether present or not, how dense they are

8. Types of trees: names of trees, estimated percentage of the total number of trees.

9. Diseases and pests: any such problems.

C. Farm forestry: block, line, or row plantation, mixed, random, scattered, species, age and size of the trees, area etc.

D. Orchards: area, species, variety, management, age, size, yield, income,

E. Grazing and grass lands: area, type, carrying capacity, management, yields, whether fodder taken, income.

F. Infrastructure: record the existing infrastructural facilities available in the watershed such as road, communication system, market, school.

G. Existing engineering structures: soil erosion control structures, dams, bridges. Mapping index for the present land use pattern may be coloured as given in the table 2.

Table 2. Colours used for demarcating various land use pattern

Sl. No	Land use	Colour
1	Agriculture	Yellow
2	Forest	Dark green
3	Grassland	Light green/ uncoloured
4	Orchards	Orange
5	Habitations	Red
6	Water	Blue
7	Roads	Black
8	Area boundaries	Thin black lines

We can have sub-divisional demarking under the agricultural land such as single cropped, double cropped and triple cropped. for this we can choose our own symbols.

We can use various symbols to demarcate the intensity (poor, fair, good) of the tree canopy in the forest area.

Similarly we can have symbols for farm forestry and agroforestry etc.

SOIL AND LAND CAPABILITY

In this section a detailed study of the soil and the land capability are presented. According to the land capability the land use pattern has to the planned in the next section. This section is written only after the detailed scientific survey is carried out with the help of the experts. From table 1 we can get the basic principle of the land use capability according to the slope of the land. Land use capability based on the other factors is given in this section.

A. Soils

Soil is the basic material for every form of production and hence the properties of the soil are: an important aspect to be taken into consideration while land capability is studied.

1. Classification: classification such as clayey soils (50 % or more clay particles), silty soils (50% or more silt particles) sandy soils (50% sand particles) and loam soils (mixture of clay, silt and sand in varying proportions).

Depending on the proportion of sand, silt and clay the soil may be further classified into sand, loamy sand, sandy loam, fine sandy loam, very fine sandy loam, loam, loam, silt loam, silt, sandy clay loam, silty clay loam clay loam, sandy clay, silty clay, clay.

2. Soil profile: description of a road cut vertical section of the soil at different locations in the watershed showing various horizons of the profile is very useful.

3. Soil fertility: very low, low, medium, and high and may be indicated as Fri, Fr2, Fr3 and Fr4.

4. Drainage: external/surface and internal (underground drainage).

5. Moisture status: slightly wet, moderately wet, very wet and extremely wet, swampy for which the symbols W1, W2, W3 and W4 respectively can be used.

6. Water movement: infiltration and permeability which are the two types of water movement and are in measured in cm/hr and classified as very slow, slow, moderately slow, moderate, moderately rapid, rapid and very rapid.

7. Organic matter: low, moderate and high.

B. Land capability classes

Identify to which class the land belongs. Have a map made demarcating the land capability classes of various areas of the watershed with a short description of the potentials and hazards. The following table (Table 3) may be used for the recording.

Table 3 Areas in different land capability classes and subclasses

Sl.No	Land capability classes	Subclasses				Total
		E	W	S	C	
	I					
	II					
	III					
	IV					
	V					
	VI					
	VII					
	VIII					

Note: E = erosion and slope, W = water table conditions, S = soil properties, C = climate. The information already given in table 1 should be combined with the information recorded in table 3 while determining the land capability.

N.B. The following method for field-work in mapping Land Capability Classes and Sub-classes may be used. But the surveyors should have a clear idea of the different types of the land capability classes and their differentiating characteristics (take the description of the characteristics for each class along with you when going for the field survey)

Quickly walk around the watershed area from one end to the other observing the various portions of the land that are similar in nature so that they can be grouped in the same class. Determine the classification number to each portion of the land in the field itself. Observe the texture and depth of the soil, percentage of the slope, extend of erosion etc. Make sketch in the field and demarcate the boundaries of

each class and label all the features observed. Take all the measurements needed to make a scale map in the office.

C. Any other feature: while surveying record any other features observed.

PROBLEMS AND NEEDS OF THE AREA

The problems of the area are mainly connected with soil and water conservation in the agricultural land including horticulture, forest land, in grass land, needs of the people and problems related to special situations.

1. Problems of Agricultural Land

a. Erosion: types and extent of erosion already present and its causes, likely hazards in future.

b. Management: analyze the hazards and causes. Mechanical measures adopted.

c. Water management: the existing defects, causes and the results; better water management practices to be adopted.

d. Flooding and sedimentation: extent and causes of flooding, measures adopted too

e. Horticulture: observe the problems and management practices and propose better methods.

2. Forest land: the forest land may be subjected to the following problems.

a. Erosion: observe the extent of the erosion and measures to counteract the erosion.

b. Management: study the management of the forest land and see how it can be further improved.

c. Biotic influences: observe the biotic factors like influence of the people, animals (domestic arid wild),

pests and disease of the forests etc. measures adopted to counteract them.

d. Any other factor: observe for any other factors that may be influencing the forest.

3. Grazing and grass land: observe the problems in grazing in the agricultural and grazing land and propose measures to improve them.

4. Needs of the people: from the discussion with the people and from the observation of the place take a stalk of the needs of the people. The needs may be basic things like food, fuel, clothes, housing, agricultural inputs, fodder, cash in hand, marketing, transport, storage etc.

5. Special problems: observe the possible special problems such as landslides, torrents, roadside erosion, areas affected by mining, shifting cultivation, environmental pollution, displacement of people, future hazards etc.

PROPOSED LAND USE

This section is prepared after completing the following:

(1) acquiring the information from the preliminary survey and PRA, (2) holding the preliminary discussion with the people after presenting the first model and getting reactions and suggestions from the people, (3) conducting the detailed survey of soil and land capability, (4) presentation of the results of the detailed survey to the people along with the second model which depicts the tentatively proposed land use and (5) getting the reactions and suggestions from the people on the land use proposed through the model. In short the proposed land use pattern is a combined decision of the people and the PIAs. This process of evolving a suitable land use pattern may take a long time and may require immense patience from the part of the PIAs from the point of view of the slope factor and the broad land use given in the

table 1 is a useful guide line. Following are the outlines for some agriculture-related land use details.

1. Agriculture: rain-fed, irrigated, partially irrigated.

2. Horticulture: type of fruit trees, area, design etc.

3. Forest: type of trees, area, planting design etc.

4. Plantation crops: type of trees, area, design etc.

5. Fuel wood: type of trees, area, design etc.

6. Fodder trees: type of trees, area, design etc.

7. Grasslands and pastures: type grasses and forage plants, area etc.

8. Cash crops: types of crops, area etc.

9. Miscellaneous: use of road sides, edges of channels, river, streams, ponds, residential areas, boundaries, marshy areas, rocky areas, rugged areas, dry up wells and pond, silted tanks, steep slopes, etc.

RECOMMENDED MANAGEMENT PROGRAMMES

After the land use pattern is finalized the management practices for the soil and water conservation are drawn up and finalized. The soil and water conservation measures may be mechanical, biological and agronomic. These measures are described in the Booklet No.604 on "Soil and Water Conservation Measures". The following guidelines will be useful for drawing up the management plan. However they may be modified and adapted to the situation of the people and place.

Table 1 gives the broad soil and water conservation plan to be adopted based on the percentage of the slope.

A. Agricultural land- rain-fed/irrigated area: The soil and water conservation practices in agricultural land may

be agronomic practices, engineering measures, diversion, bench terraces, grassed water ways and any other soil conservation structures.

1. Agronomic practices: crops proposed/ rotations/ cultural- operations/introduction of improved seeds/ use of manures and fertilizers, improved weed control, green manuring, use of improved implements, plant protection measures, yield, cost of cultivation, etc.

2. Engineering Structures: soil class wise and slope category wise engineering measures should be mentioned in a chart or table form. This section also includes the justification for the proposed measures. Once the soil conservation measures are proposed specification for each individual measures with plans, designs calculations and drawing should be developed. Finally the estimated cost of each mechanical measure should be calculated.

3. Diversion: to build the diversions we need the basic data on catchment area, size, alignment to shown on map, slope of land etc. Further based on the expected runoff we have to make the design section and its dimensions, design grade, capacity, cost, earthwork and sodding.

4. Terraces: determine the area to be terraced, whether repair or newly to be made, length, width, height and number of terraces etc. to be determined. Determine the earth work needed to make the terraces and estimate the cost of the terracing separately for the new terracing and repair of the old.

5. Waterways: determine the places waterways have to be constructed, their lengths, catchment area, expected run off, alignment, slope, design, combination of any drop structures its size and dimensions, amount of earth work, sodding and stabilizing the earth work, cost of earth work etc.

6. Structures: any other structures could be included in the cropping land. Decide the location, type, design, dimensions and cost of the structures are calculated.

B. Forest land: soil conservation practices implemented in the forest areas may be distinguished between those in the good forestland, degraded forest land, scrub (shrub and bushes) areas with high potential for growth, scrub area with low potential for growth. The engineering measures adopted in the various forest areas depends on the type and extend of erosion the percentage of slope etc.

1. Management: specify the management practices such contour planting, dense plantation, trenches and sunken structures, close plantation in the lines, strip cropping, contour plantation of grasses etc. in the forest area which will conserve the soil and water in the forest area. Choice of suitable species, planting design, digging of pits and planting, inter cultural operations, use of cover crops, thinning and lopping of branches, multi-tier canopy etc. are other management practice that will enhance the soil and water conservation.

2. Management of degraded forest: here the management practices will be those that regenerate the forest and those that reforest the area. Gap filling, reforestation of the deforested area, choice of species, design of plantation, digging of the pits, plantation, protection of seedlings, moisture supply during dry season, intercultural operations, thinning and lopping of branches and cost benefit calculation are the items included in this section.

3. Management of scrub area with high potential: scrub areas are places coming under dry and rugged terrain with bushy and thorny shrubs. Some of those areas have high potential for good vegetative growth while the other have very low potential. Select the species, planting design

and management practices which will suit to the high potential areas and low potential areas. Calculate also the estimated cost-benefit from the programme.

4. Management of scrub area with low potential: specify the management practices, choice species, planting design, planting method, intercultural operations, moisture conservation practices, cost-benefit estimation are the items that considered in this section

5. Engineering structures: any type of engineering structure may be constructed in all the above mentioned forest areas depending on the type and extend soil erosion and the slope of the place. The type, size, design, construction details, materials used, cost of construction are to be specified for each structure to the constructed.

C. Grazing & pasture land: specify the management practices for establishing and maintenance of the grazing and pasture land, the type of grasses chosen, planting method, incorporation of fodder trees, inter cultural operations, cost-benefit analysis and the suitable mechanical soil and water conservation measures along with their specifications and designs.

D. Farm forestry: specify the type of trees, method of planting, design, inter cultural and management practices suitable for the soil and water conservation m the area of the farm forestry. Beside specify the mechanical measures along with the specifications suitable to the area. Include also the cost-benefit analysis of the farm forestry.

E. Orchards: specify the area, types of fruit trees, method of planting, design, management practices, mechanical measures to be introduced; cost benefit analysis etc. is to be included in the plan.

F. Fuel wood: specify the area, types of trees, design

plantation, planting method etc. and cost-benefit analysis is included in the plan.

G. Special problems: land slide, torrents and road side erosion are the usual problems.

1. Land slide: locate on the map, describe the area, estimate the extend of the area affected, study the problem associated with damage to cultivated land, road, forest, orchards etc., control measures, trees and grasses plantation, reinforcing structures, breaking of land slide face etc. are related to land slide control.

2. Torrents: study the problem, damage, causes, tributaries involved, location of the affected site on the map, alignment, grade and cross-section, maximum depth of flow, amount of debris and boulders coming, types of structures spurs and barrages and their designs structures, vegetative measures, cost-benefit analysis etc. are involved.

3. Road side erosion: study of the problem under various conditions like cut slope, hill slope, road drains and shoulders, gully control etc. Specify the control measures and their design specifications and the cost-benefit analysis etc. are included in the plan.

COST AND BENEFITS

In the cost and benefits the expenditure, income and other benefits are estimated in this section.

1. Expenditure: expenditures for implementing soil and water conservation on agricultural land, forest land, agro and farm forestry, grass and pasture land, fuel wood plantation, orchards etc are computed.

2. Income: The expected additional income due to the implementation of the soil and water conservation is calculated.

3. Benefit: Cost benefit ratio in terms of money is first of all calculated. Then assess the expected non monetary (social, political etc. benefits are estimated and recorded. Thus both the social and economic benefits are estimated and recorded. The socio-economic benefits may be general (population and number of families benefiting), income (the amount by which the average income of the family will go up), employment (the number of man days generated etc.)

PHASING, FINANCING, ORGANIZATION

1. Phasing: in this section plan out the phasing of all the works, prepare a schedule of works that are done simultaneously and in rotation, purchase of materials, record keeping of the materials stocked and released, record of the accounts, labour record etc.

2. Financing: mention the types of finances internal and external, sources, amount, loan, subsidy, interest free loans, contribution in kinds, labour etc.

3. Organization: define and describe the organizational structure, mention clearly who is doing what, what is each ones responsibility, to whom he is accountable etc. The vertical and horizontal structure and the relationship should be very clearly defined. This is very important for the smooth running of the works planned.

Concluding remarks

Once again the readers are reminded that this is only one of the possible models for planning watershed management; there may be several other points that can be included in these guidelines for the planning of the watershed. However it should be kept in mind that watershed management is a very complex approach in the

area development and there can be no limit to the number of activities and programmes that can included.

In every watershed plan the road, transport, electrification and other facilities should be given top priority. Further processing, storing and marketing of all the products in the watershed should be thought off as a continued activity of the implementation of the watershed.

Chapter-12

Soil Conservation Measures

Over the years it has been my experience that in spite of undergoing several training programmes on soil conservation most of the trainees do not get a clear idea of the different methods of soil conservation. As a result they are unable to identify the appropriate soil conservation measures suitable to each location and to implement them properly. Often they are not even able to distinguish between various soil conservation measures. Therefore the purpose of this chapter is to enumerate all the possible soil conservation measures and to distinguish between them so that people will have a clear idea about them. Soil conservation is the first step in water conservation. Since internet sources are full of images of various types of soil and water conservation this chapter does not include them. Readers are encouraged to go through those images of various soil and water conservation structures and try to understand the structural and constructional details.

Watershed management at present is one of the most accepted forms of developmental approach. It begins with the soil and water conservation but is expected to move on to the natural and human resource management and finally to community building. Water is the most essential item for every living being. Soil is a porous material and acts like a sponge capable of absorbing and retaining the water. Thus soil acts as the vessel in which water is stored in the nature.

This retained water is called soil moisture part of which is available to the plants. Therefore for the plants to obtain water from the soil there should be sufficient water stored in the soil. For this first of all the soil should be stored or preserved. The question of soil conservation becomes most crucial because soil is very easily eroded within no time. At the same time it should be remembered that it takes hundreds of years to form one centimeter thick layer of soil. In soil mainly three kinds of water: soil moisture, free flowing water and stagnant water. The free flowing water is mostly and ultimately lost into the lakes or seas. The main objective of water conservation is to maximize of the storage and utilization of free flowing water in a watershed.

Most of the cultivated lands are slopping and require one or more types of soil conservation measures. The topography and agro-climatic conditions are so varying in our country that one should have the ability to discern what type of soil conservation measures a particular land area requires. This means he should have a clear idea of the various soil conservation measures and their suitability to a particular geographical area where the soil conservation is a problem. One should have the ability to diagnose the type of soil conservation problem and to propose appropriate treatment to solve each problem. Often he should apply a combination of treatments in which case he should have a clear idea of the combined effect of various in the soil conservation measures.

Most of the cultivated land needs application of long term soil conservation measures followed by reorganization of land use pattern efficiently including son moisture conservation, improvement of soil productivity and cropping and farming systems.

There are many ways of conserving the soil. Numerically

speaking there are about 58 ways of mechanical soil conservation, 13 ways of biological soil conservation and 20 ways of agronomic soil conservation. Often both the trainers as well as trainees get confused between the various types soil conservation measures. Some of them of course are very much similar to each other. In the field level situation a combination of a number of soil conservation measures have to be applied. Therefore one should have the ability to decide which combination of soil conservation measures should be implemented at given location. This chapter intends to enumerate all the possible types of soil erosion control measures and their combined applicability to various conditions of soil degradation and erosion. Several of the measures enumerated may not be found in the conventional literatures. They are collections from the field practices observed by me in many parts of the country.

As already mentioned there are mainly three broad types of soil erosion control: mechanical, biological and agronomic. Under each of these there are many types of individually different measures. The readers are strongly reminded that it is a combination of several soil erosion control measures drawn from the mechanical, biological and agronomic types that becomes effective in the actual field conditions.

We cannot change significantly the climate and the inherent soil properties of a place. But we can do something to modify the other factors of topography and vegetation to reduce the soil and water losses. However before we discuses each method we need to know the factors that should be taken into consideration in determining the type of soil conservation measures.

FACTORS TO BE CONSIDERED

The following factors and the mechanics of erosion by water and wind are to be assessed before we implement any of the soil conservation measures. They are briefly described here.

1. Physiography

The physiography refers to the size, shape, relief, drainage, mean elevation, land slope etc. Both the volume and rate of runoff increases as the size of the water shed increases. The size of the watershed is an important factor to compute the peak rate of runoff which is essential for the designing of the drainage channel. The longer and narrower the watershed the time of concentration of water (water retention in the water shed will be longer and lesser will be the runoff.

Relief designates the elevation difference between any reference points on the basin with respect to outlet elevation. Greater the elevation lesser will the concentration effect. At the same time longer the distance between the points greater will be the concentration effect or runoff water. Ultimately the combined effect of the elevation difference (slope factor) and the total length (length of slope) between the points will be the actual concentration effect.

Land slope has major implications for the land use. The speed and the extend of runoff depend on slope of the land. Greater the slope more will be the velocity of the water flow and still greater win the erosion of the soil. The complex mathematical expressions of the multiplying effect of the slope on the velocity, erosivity, the quantity of soil eroded and the particle size is expressed here in words as follows.

"When the slope is increased by four units the velocity of water flowing along the slope is doubled; if the velocity

is doubled the energy and the consequent erosivity is increased four times; the quantity of soil eroded will be increased by 32 times and the size of the particles that can be transported by pushing or rolling is expected to increase by about 64 times."

When the slope is more or greater the number of contour lines will be more per unit area. Based on this relationship we can estimate the percentage of slope of a given area using the following formula: S = MN/A x 100, where S is percentage of slope, M is total length of all contours within a watershed in meters, N is the contour interval and A is the area of the watershed (m^2). There are several methods of of determining the degree of slope described in the earlier chapters.

The degree of slope determines the land use for annual crops, plantation crops, land reclamation, depending on soil depth, stoniness, etc. Hence the length and degree of slope is important parameters to be considered in the watershed management. Roughly we can say that up to 3% of the area is good (or bunding, 4-7% slopes is suitable of contour bunding, 8-10% slope for broad base terrace, 11-15% slopes for broad terrace, 16-20% slope for broad bench terrace, 21-25% slope for bench terrace, 26-30% for narrow bench terrace, 31-50% slope is suitable for horticultural and fodder trees and between 51-100% slope the land should be used for planted forestry for fire wood and small timber trees and above 100% the land should be left for natural forest. This division is arbitrary and is based on the practical experience in the field.

The total rainfall and the drainage density are factors that need to be considered for the watershed management. The factors affecting drainage are related to the susceptibility of soil to erosion, runoff pattern, sedimentation and locating

erosion control structures and erosion itself.

$$\text{Drainage density} = \frac{\text{Total length of all streams (km)}}{\text{Catchment area (km}^2\text{)}}$$

The drainage map of an area may serve as a beneficial tool for the understanding and the preparation of the erosion assessment. From the drainage map we can understand the drainage pattern of an area referring to the design of the stream courses and their tributaries. The drainage may be fine, medium or coarse textured depending on the type of soil. Clay soil will exhibit finer drainage structure while the sandy soil will show coarse structure. Drainage patterns can act as guidelines to locate vulnerable areas requiring different kinds and degree of soil conservation measures.

2. Soil properties

Soil properties refer to soil series and soil phases, physical, chemical and biological properties, hydraulic soil groups and soil moisture regimes. Based on the runoff potential there are four hydraulic soil groups: (a) low runoff potential, (b) moderately low runoff potential, (c) moderately high runoff potential and (d) high runoff potential. The runoff very much depends on the infiltration and permeability of the soil.

3. Vegetative cover

A dense vegetative cover is the most powerful means to reduce the soil erosion. In relation to the vegetative cover the following hydrologic conditions may be identified: (a) poor (heavily grazed or regularly burnt, litter, small trees and brush are destroyed), (b) fair (grazed but not burnt, there may be some litter but these are not protected), (c) good (protected from grazing, litter and shrubs cover the soils).

4. Land use practices

A record of the present land use practices followed by the farmers in a region is essential for further planning and reorganization of land use according to its land use capability classification, to get sustained production.

5. Nature and distribution of rainfall

Rainfall data is collected at different locations in the watershed and the mean is estimated. Besides total annual average the duration, intensity, frequency etc., of the rainfall are also important information for the watershed management.

6. Prediction of peak run-off rate

The peak runoff refers to the maximum level of runoff happening during a period of very high storm which occurs once in several years. In soil and water conservation measures, the design of hydrologic structures, quantitative estimates of runoff rates, volumes and distribution are to be worked out. The channels and other structures are planned in such a way that they will be able to carry maximum runoff, which can be expected in a specified recurrence interval.

7. Floods and droughts

Related to the peak runoff is the flood situations which also occur either every year or once in few years. Needless to say that the soil conservation measures implemented should be able to withstand the peak runoff flood waters. Whereas, in the case of drought the soil conservation structures should be such that they store sufficient moisture in the watershed area to tide over the drought period. Therefore we should have sufficient data on the flood and drought occurrence in the watershed area.

8. Socio-economic factor

The watershed management begins with the implementation of soil conservation structures. But it should cross over to the economic programmes and finally it should culminate m social development programmes. Even in implementing the economic and social programmes the cultural factors are to be taken into consideration.

MECHANICAL MEASURES

The mechanical measures for soil conservation, consists of any structure that is erected to hold the soil and thereby prevent the erosion. They are described as follows.

A. Bunds

Bunds are ridges or embankments or long and narrow projections constructed on the surface on the land at selected places and in selected directions. They are constructed with a number of materials, in different. sizes, shapes and heights. For more details about the type and construction of bunds the reader is requested to refer the booklet No. 593 on "Bunds and Terracing". In this booklet the types of bunds described are with reference to the construction material and way of construction. Bunds are also constructed in contour or graded contour line.

1. Mud bond

The mud bunds are constructed using the soil. This is constructed when the slope is minimum. This is common in farm lands and in places where rainfall is average and above. The mud from the lower side of the proposed bund is dug up and placed in position to make the bund. For more details about bund making the readers may consult the Booklet No. 593 on "Bunds and Terracing". In places where there is above average rainfall there should be drainage

from the plots in order to drain out the water.

2. Loose rock bund

In loose rock bunds instead of soil, rocks are used. The rocks are piled up in the form of a bund or wall. Rocks of different sizes are arranged in such a way that the small ones are fitting in between the big ones. This is constructed in areas where the rainfall is less than average and the rainfall is erratic. Stone bunds are constructed in places where there are plenty of stones available at very cheap rates and to withstand the sudden on rush of rain water. They reduce considerably the velocity of the rushing water. However the water is not retained some soil may be retained.

3. Loose rock cum soil bund

In this type the space between the rocks is filled with the soil which acts as a cementing agent and hence this method is able to retain the soil also.

4. Bund cum vegetation

Trees; shrubs or bushes are planted on the top of the bund; or on one side of it, by doing this the bunds are strengthened.

B. Walls

Walls of different heights are made in certain places for the conservation of soil and water. They are of different types.

1. One sided mud wall

These are modified bunds constructed on land have more slopes than the places where bunds cannot be constructed nor terracing can be done immediately. The down side of the bund is beaten and pressed in such a

way that it looks like a wall. The upper side though shows bunded structure merges with the land on the upper side. This is possible only in clay soil. Grass is allowed to grow on the side of the wall so that the waIl will be durable.

2. Double sided mud wall

In this type the wall is built higher and hence both the sides have to be built by beating and pressing the soil to make a compact wall. By growing suitable grasses we can maintain the wall durable. It is also highly advisable to cover the double sided wall with any material to protect it from erosion due to rain.

3. One sided stone wall

Instead of mud, stones are arranged at an angle of stability or the angle of retention. This is much more durable than the mud walls.

4. Double sided stone wall

Stones are arranged on both sides of the wall with moist soil pressed and compacted in between.

5. Loose rock wall

Rocks and stones are arranged without any soil of cementing material in the form of a short wall. This is useful to check and reduce the velocity of the rushing water and soil coming along with it under erratic rainfall conditions.

C. Terraces

Terrace is the cut and leveled portion of the slope. Depending on the degree of slope the width of the terraces will vary. Greater the slope lesser will be the width of the terrace. Depending on the width of the terrace there are different types of terraces. With reference to slope the

terraces may be bunt in three ways: leveled terraces, inward slopping terraces and outward slopping terraces. For irrigated crops like paddy leveled terraces may be better. When one needs drainage through channel then inward slopping terraces are better. But if the drainage is natural then outward slopping terrace is better. For more details about terracing the reader is advised to consult the Booklet No 593 on "Bunding and Terracing". In this booklet only the different kinds of terraces are enumerated.

1. Broad base terrace

Generally broad base terraces are made on land slopping between 8-10 per cent.

2. Broad terrace

Broad terraces are constructed on lands slopping between 11-15 per cent.

3. Broad bench ten-ace

These are lesser in width and are constructed on lands with slopes ranging between 16-20 per cent.

4. Bench terrace

These are still narrower terraces constructed on lands with slopes ranging between 21-25 per cent.

5. Narrow bench terrace

These are terraces of least width and constructed on slopes ranging between 26-30 per cent.

6. Continuous ten-ace

Terracing is done along the whole length of the contour, it is called continuous contour terraces.

7. Broken or intermittent terraces

When terracing is done in a broken not continuous form it is called broken terraces. They can also be called intermittent terraces.

8. Interlinked terraces

This is a way of constructing at least two rows of interlinked terraces at alternate heights along the slopes. Each terrace interlinked two other terraces of the opposite row, one on the upper side and another on the lower side. The width of the terrace depends on the percentage of slope of the land. The design looks like criss-cross arrangement of the terraced beds. The linkages between the alternating terraces in the parallel rows helps in moving bullocks and implements up and down from one terrace to the other on the slope. Also it forms a zig-zag path for the people to go up and down the slope.

9. Intermittent square terrace

These are square shaped platforms cut on the slope to plant each tree or to conserve soil and water around the trees already planted. The trees may be fruit trees, plantation crops like coconut, rubber, cocoa, coffee, pepper, nutmeg, clove, aracanut etc. The trees are usually planted in contour line and each tree will have a square or semi-circular shaped terraced space to conserve moisture, nutrients etc.

10. Platform terrace

They are initially made as intermittent square or semicircular terraces around each tree planted in a contour line initially. Later they are extended on both sides forming a contour platform cut across the slope. This is very common for plantation crops or orchards planted in contour line.

11. Half circled terrace

Instead of square shaped intermittent terraces half circled terraces are cut for each tree on the slopes in the second year of plantation. The trees are planted alternatively or triangular design between the adjacent rows across the slope. In each terrace sufficient slope is given to the hillside to facilitate collection of rain or irrigation water.

D. Gully check

Gully is a common term used for a variety of soil erosion effects ranging from few centimeters to three meters in depth and up to 18 meters in width. In some places gullies are called channels or nallah in Hindi varying from small channel to very big ones. The gullies are classified into very small gullies, small gullies, medium gullies and deep and narrow gullies (Booklet No. 532). This classification according to me is too broad. For example very small gully according to the conventional classification varies from few centimeters to three hundred centimeters. The range is too much. Similarly in the other classification too the range of depth and to some extend the width is too much.

The gullies may be with or without perennial flow of water. The barriers created for checking the soil erosion through various types and sizes of gullies are commonly called gully plugging or gully checks or channel/nallaha checks/ bunding in general. Gullies are two types: temporary water flow and permanent water flow.

Gullies, with permanent water flow are called streams and the checks made in them are called check dams. While checks that are made in gullies with flow of water only during the rains (seasonal) are called gully checks or gully plugs. Since the flow of water in the gullies is so much forceful the checks should be strongly constructed.

The needed strength of the checks depends on the force of flow of water (quantity of water, percentage of slope, length of the slope, type of the soil etc.) and duration of rain and flow. Therefore the strength of the checks should be varying by adopting suitable construction materials and method. The different types of checks described here are precisely according to their variation in their strength to withstand the flow of water. They can be constructed in a number of ways. Most of them are explained here.

The width of the checks obviously depends on the length of the checks. More the length greater will be the width of the checks. As a thumb rule we can say that for every 9-12 Inches length the width of the check should be one inch (1:9-12). Therefore for 10 feet long check a minimum of 10 inches thickness is needed. However this will vary according to the place and according to the force of flow of water. The width of the checks given here does not include the width of the foundation. In some cases the design and nature of the foundation should be given very serious consideration. Otherwise the gully checks will not survive very long.

The gully checks should be permanently built. Only then it will achieve attain its purpose of preventing the increase in the depth and width of the gully and also level the gullies. Therefore it is highly recommended that only permanent and nonpermeable checks/structures should be built across the gullies with perennial water flow.

In a gully there will be a number of checks installed at regular intervals (distance between two successive checks). The main principle to be followed under such conditions is to maintain proper interval between the checks. The top of the lower check should be at least one foot higher than the ground level of the upper check. Anything less than this

will result in' the erosion of the soil. The height of the checks will be determined according to the percentage of slope and the distance between two successive checks and the depth of the gully. For a fixed height of the check the interval will vary with variation in the percentage of slope: greater the percentage of slope lesser will be the interval between checks and vice a vice. Similarly for a fixed distance the height of the checks vary with the percentage of the slope of the gully. The length of the checks depends of the width of the gully. The type of the gully checks described here are in the order of decreasing strength.

1. Concrete checks

When the force of the flow is very high strongly built concrete checks are necessary to control the gully erosion. Sufficient foundation should be laid at the bottom and on the sides. For the reinforced concrete checks normally 1:3:6 to 1:4:8 cement, sand and metal mixture is used for the construction of the concrete check.

2. Sized stone and cement

Well sized stones are used to construct the gully checks. Well constructed checks are as strong as the concrete ones. The cement mixture should have the proportion of at least 1:4 cement and sand. Instead of sized stones we can use unsized stones also.

3. Brick and cement

In this type well baked bricks and cement are used to construct the gully checks.

4. Loose rock double sided wall with cement

Instead of the sized stones irregular stones are used for the construction of the checks. The stones are arranged in

such a way that both sides of the wall will be in the same level. The stones are jointed with the mixture of 1:4 cement and sand.

5. Loose rock double sided wall with pointed cement

Checks are made of any irregular shaped stones collected from the vicinity and are arranged in such a way that there is a wall on both sides. The space in between may be filled with small stones or soil. Finally the space between the stones is filled with the cement

6. Loose rock double sided wall without pointing

This type of checks is made in places where the force of flow is less compared to the previous cases and which allow the water to drain out through between the rocks while retaining the soil. Eventually the spaces between the walls will get filled up with the incoming mud and the wall becomes impervious.

7. Loose rock one sided wall pointed with cement

The one sided walls are more suited to gullies with greater percentage of slope and in cases the upper side of the gully check is leveled at the time of construction. The construction of this type of wall is similar to the above mentioned one except that the stones are arranged in level on one side only. Obviously this type of wall is less strong than the previous one.

8. Loose rock one sided wall without pointing.

The construction is same as the above mentioned ones except there will be no use of cement. On the upper side of this wall is filled with soil and stones.

9. Brush wood checks

This is a fencing structure across the gully and usually made in places where plenty of wood is easily available. The structure consists in vertically planted posts and the horizontally fixed long poles. (Hereafter posts refer to vertical structures and the poles refers to the horizontal, structures). The vertical and horizontal structures may be made of any material such as concrete, iron, live wood and dead woods. The space between the vertical posts and the horizontal poles can vary from very close to several feet apart. The space between the vertical posts and the horizontal poles will be covered with twigs, leaves or any other vegetative material so that the soil eroded in the beginning will come and settle against them making a barrier to further soil erosion. In some case the space filled at the time of the construction itself. Whatever be the material of construction the brush wood check dams should be durable. When the brush wood check is made of live wooden material it can considered as a biological measure also. However it should be remembered that here we are discussing the mechanical structures. There are several types of brushwood dams as explained here.

a. Live posts and poles

The branches of trees that sprout in to new trees are planted as post. The horizontal poles are planted into the soil on both sides of the gully and tied to the posts. Both the posts and poles strike roots and sprout into branches forming an interwoven vegetative structure. Obviously this can be done, only in deep and narrow gullies having deep soil layer from the top to the bottom of the gully and in places where easily rooting and sprouting trees are available.

b. Live posts and dead poles

The construction is same as explained before except that it can be constructed in places where the sides of the gullies are rocky or stony.

c. Dead posts and poles

Dead wood collected from the nearby areas is used to construct the brush wood checks.

d. Concrete posts and poles

Concrete posts and poles are either planted or constructed in situ to form the brush wood check.

e. Concrete posts and wooden poles

The concrete posts are constructed in situ or brought from the place of fabrication. The wooden poles are fixed horizontally.

f. Live posts both sides of mod bond

In this case a closely planted brushwood posts will be lining on both sides of a tapering and high mud bund constructed across the gully. In this case the posts planted are thinner than the posts mentioned above. They are branches of the trees which strikes root and sprout easily.

g. Dead posts both sides of mud bund

Instead of the live posts dead wooden branches of any kind of trees are used.

h. Conically planted double line posts

In this case the brush wood posts are planted in two Iines at suitable distance but slanting towards each other in pairs and crossing at the required height of the check. When constructed it will look like a conical fencing. Reapers are fixed horizontally to strengthen the fencing.

We can construct this type with live or dead posts including that of concrete and iron.

i. Straight and slanting line

In this type of brush wood checks two lines of brush wood posts are planted at a suitable distance. The posts in the upper side line will be planted straight while the posts in the lower side line will be planted slanting towards the upper line and each post in the lower side line will be crossing with the corresponding post in the upper side line at a height required for the brush wood. Reapers may be fixed horizontally to strengthen the brush wood structure. In this case also we can make it with live or dead posts including that of concrete and iron.

10. Sand bags

Sand bags are easy material for constructing checks where there is water flow in the gullies. The sand bags are arranged in such a way that they form a well shaped check across the gully.

11. Building sides

Often the sides of the gullies are prone to land slides or massive soil erosion causing the increase of the width of the gully. By building the sides one can retain the gully and used as drainage or a channel.

12. Paving the bottom

The gullies could be paved with stones or bricks in case one wants to retain the gully and use it as a drainage or channel.

13. Tetra pod cement blocks

They are precast very hard and heavy cement blocks with four prongs used for controlling the seashore erosion.

Once they are placed on the sea shore or river banks they remain like a tripods capable of resisting back and forth onslaughts of sea waves or heavy rush of river water. They are usually placed interlocked manner that no wave can move them and thus giving stability to the seashores or riversides which are subjected to crashing waves or rush of flowing water.

E. Gibbon structures

The structure of gibbon constructions consists in having a very strong and thick galvanized wire mesh holding small or big boulders in the form of a bundle. The shape of the bundle may vary from round to cylindrical. Gibbon structures can take the place of bunds, walls of terraces, sides of channels and gullies, checks, pillars etc. and are usually made where strong foundations are not possible to make the above mentioned structures. Galvanized wire mesh is used in the case of permanent gibbon structures whereas for temporary structures ropes and wires of lesser strength can be used. Based on the shape and material of construction we can identify several types of gibbons.

Gibbon structures can be used for gully checks, for one side walls to prevent landslides, to reinforce the side of the streams prone to landslides, to make double sided walls, stone path ways etc.

1. Galvanized wire and stones

Galvanized type of thick wire is used. Depending on the size of the stones the mesh size is decided. The mesh is spread on the ground in the place where the gibbon is to be constructed and the stones are piled up in the shape one wants. Then the mesh is taken over the pile and fixed firmly using proper wire tightening instruments so that all the stones in the pile will be held firmly in place. It will look

like a bundle of stones but in any predetermined shape. We can construct gibbon structures in any size and shape and length. We can also construct them in layers one above the other in the case of permanent gibbon structures. They maybe two types: the gaps filled with high quality cement mix or without cement mix. The cemented ones will remain like a solid heavy block capable of withstanding the onslaughts of water while the one without cement will allow the water to rush into the block while the stones and wire mesh will neutralize the onslaughts of the rushing water.

2. Ropes and stones

Any type of rope material is used in the place of galvanized wire mesh. Though theoretically this is possible for practical purposes we cannot rely on this. Soil conservation is a long term planned activity. Therefore gibbon structures with ordinary rope material will not be useful for soil conservation. They also can be two types: the gaps filled with high quality cement mix or without cement mix. The ropes are not lasting and hence its effectiveness is poor. However if it is reinforced with high quality cement mix it will remain like heavy block concrete resisting the onslaughts of rushing water.

3. Gibbon pillars

Wire mesh or rope mesh made in the form of cylindrical shape is filled with stones and finally when it is filled it will look like a pillar. Using these pillars further horizontal structures can be attached and made strong. Gibbon pillars can be used for constructing temporary check dams. They also can be bound by galvanized wire mesh or strong ropes, cemented or non cemented.

F. Mechanical water channel

The constant or frequent flow of water, through the channels, whether irrigation or drainage, cause soil erosion in a massive way. The channels can be protected in several ways. The most common ones are briefly explained here.

1. Concrete channels

If the channels are big it is advisable to use reinforced concrete at the bottom and the sides.

2. Cementing

If the channels are small cementing the bottom and the sides would be sufficient for preventing the soil erosion.

3. Paving

Paving the bottom and the sides of the channel with stones, bricks, tiles etc. will help in controlling the soil erosion in irrigation and drainage channels.

4. Stone spreading

Spreading boulders on the edges of the streams and water ways is another effective way of controlling the soil erosion.

5. Gravel spreading

If the water channel or drainage is very gently sloping or almost leveled spreading pebbles or gravel would be enough to control soil erosion.

G. Trenches

Trenches are dug in different patterns across the slope to control the soil erosion by trapping the runoff water. On lands more than 25% slope trenches should not be made. In other words for a two feet wide trench the difference in

height between the upper and lower edges should not be more than half a foot. Trenches are constructed in places where more rain water is received than that can be held by the bunds. Further the number of trenches dug in a unit area is more when the rain fall is high. Trenches of about one to two feet deep and wide are dug in any convenient direction or strength. For the control of the soil erosion trenches are made along the contour line. The following are some of the important types of trenches.

1. Continuous

When a continuous trench is made in contour line it is called a continuous trench.

2. Intermittent

These are trenches of shorter lengths dug in the contour or no-contour line with a certain amount of gaps in between. Where continuous trenches cannot be built due to rocks or stones intermittent trenches are dug.

3. Intermittent alternate

When the intermittent trenches of two successive lines are alternated in position (gaps and trenches) they are said to be alternative.

H. Pits

Pits are either round or square. Pits can be dug on land (up to 33% slope.. Pits are more suitable where even intermittent trenches cannot be dug. This happens when the land is too stony or rocky. The pits are dug wherever possible.

I. Others

Besides the above mentioned soil conservation

measures there are a few mechanical structure constructed for the control of soil.

1. Check dam

Small dams built across the perennial streams to store or divert water and ultimately to control the soil erosion are check dams. Check dams may be built of mud, concrete, stones, bricks etc. For the details of construction of check dams the readers may refer to Booklets Nos. 573, 574, 579 & 576 on Investigation and planning, Design, Construction and Maintenance Earthern dams. In the case of check dam across the perennial streams the over flow is allowed by the side of the dam over a structure called spillway.

2. Anicuts

Anicuts are like check dams except that the over now is allowed over the dam itself. No spill way is constructed as in the case of check dam. Water is impounded on the upper side of the anicut. Since the water is flowing and falling to the ground there is all possibility of cutting the soil at the foot of the anicut. In order to prevent this a check wall of about 2-4 feet called "shoe" is made a few feet away from the spot waterfalls at maximum flow. This is built of concrete or stones with cement in such a way that water falling from the anicut can be stored at a certain height of 2-4 feet. This water acts as an absorbent of the force of water falling.

3. Wiers

Wiers are structures constructed across the channels and streams. These structures have rectangular of triangular shaped notches to allow the water to over flow. Besides soil erosion control weirs are also used to measure the quantity of water flowing through the streams or channels.

J. Ridges and furrows

Ridges and furrows are usually temporary mechanical structures though we can have them pern1anent too on a gently sloping land with plantation crops, fodder crops, horticultural crops or forestry plantation. In seasonal cropping the ridges and furrows are temporary and small in size. In the permanent cultivation the ridges and furrows are made big. The effect of the ridges and furrows are suitable in low rainfall areas for the conservation water. According to the shape of furrows and ridges they may be classified into three types.

1. V-type

The ridges and furrows are made in such a way that between two ridges the furrow will be in the shape of English letter V. In this design the ridges and furrows will be small in size and the ridges will have sharp edge on the top.

2. U-type

The ridges and furrows are made in such a way that the space between two ridges will be in V-shape. The tope of the ridge will be round. The ridges will be bigger than the V-type. The bottom of the furrow will also be round.

3. L-type

In this type the furrows and ridges will be still bigger and the space between two ridges will be wider in the form of a channel with L-shaped sides. The top of the ridges may be fiat with steep sides or broadly round. The furrows will be flat at the bottom forming like a broad channel.

BIOLOGICAL MEASURES

Biological agents like trees, shrubs, bushes, grasses are

used in controlling the soil erosion. These are planted alone or along with mechanical measures. The trees, shrubs, bushes and grasses are planted in such a way that they are able to control the erosion to a great extend. They may be planted alone or in combination. However it should be remembered that the biological measures will have to be applied along with the mechanical measures in the areas where perennial cropping systems like forestry and plantation crops are cultivated. Whereas where seasonal cultivation is done one should; follow a combination of mechanical, biological and agronomic measures.

The various measures under biological control are so similar that one tends to over simplify them both in the understanding and practical application resulting in the failure of the programme. Each individual measure will be dealt here even though they are very much similar.

A. Tree plantation

Land above 30% slope should not be put under seasonal cultivation and the land above 45% slope should always be put under perennial forestry which should never be subjected to clear felling. One can only go for selective felling of trees in areas above 45% slope. But in some areas like origin of springs and streams should be kept under perennial natural forest at least 50 meters radius of the origin. From this area no felling should be done at all. Similarly areas which are so steep no felling should be done.

A word about selective felling is also necessary. Some of the ideas about selective felling will be too much for anyone to digest. However the ideas have to be projected before they are to considered. If we want to cut and fell a tree even selectively on to the ground some people have to go on the ground to the spot of the tree; it has to be cut

manually or using mechanical saw; the tree will fall to the ground crushing some other trees, shrubs and bushes; then the branches have to be chopped and left in the forest if we want only the trunk; but if we want the branches also we have to cut them into manageable size. Then the trunk has to be dragged down to a place convenient enough to saw it into sawn timber or to load it into a truck. In some cases a road has to be -constructed to the spot of the tree cut. In all these cases there will be unavoidable erosion of soil.

Therefore it is highly advisable that above 45% slope selective felling of trees is done by means of helicopter. Helicopters should be used for people to slide down to the exact tree to be cut, chain the tree to the helicopter and then saw the trunk. As the trunk is fully cut and detached the helicopter should lift the tree along with the person who cut the tree to a convenient place, in the plains for chopping the branches and to saw the trunk into timber.

In this case all the branches, leaves, bark and waste from the sawing of the timber can be utilized. In other words every bit of the tree will be utilized. This method apparently looks very expensive. But if we calculate the cost of irreparable harms of soil erosion due road construction to the felling spot or dragging of the timber down through the slope and the cost of road construction or employing an elephant to drag the timber down to the plains and to load and transport the timber by truck and the cost of laborers etc. and the value of the amount of time required to complete the felling of one or few tree in the traditional way and considering the additional income from the branches and the leaves selective felling by means of helicopter will be much cheaper. From the point of soil erosion control alone helicopter felling is cheaper.

The point being driven here is that under no condition

any land above 45 % slope should be left without tree cover even for a day. Because, on that day a storm can occur and thousands of tones of soil can be eroded.

Besides this tree cover on land above 45% slope is essential for the preservation of the springs and streams which are the sources of water for the big streams, small and big rivers.

It should be remembered also that the planting and caring of trees on land above 45% is very difficult or almost impossible. Hence the best way perhaps is to saw the seeds already and allow the natural growth of the plants except areas having transport and accessibility. After having said the basic policy with regard to the utilization of land above 45% slope let us see the various methods of biological control of soil erosion. In all the tree plantation methods which are explained here the soil erosion is controlled by the canopy cover.

1. Random plantation

Trees are planted at random with the same type of trees or different types. The first is called monoculture and the latter is called polyculture. Areal seeding also results in random plantation. Random plantation is done in areas where spring originates, both sides of the streams and rivers and in areas where human beings cannot reach.

a. Monoculture

When the same species is planted in an area at random it is called random monoculture plantation.

b. Polyculture

When different species are planted at random in an area it is called randomized polyculture.

2. Line plantation

Trees are planted in line and there are different types of line plantation such as (a) contour line, (b) square design, (c) rectangular, (d) hexagonal, (e) strip plantation, (1) boarder plantation on the boundaries, edges of the streams, canals, roads, bunds, boundaries of plots etc. Line plantation can be done only in areas where people can easily reach.

3. Block plantation

When trees of different species are planted in different blocks it is called block plantation. Each block may be of few to many acres. For commercial usages it is better to plant in blocks. Block plantation can also be done only in areas where people can reach easily.

4. Orchards

Planting of fruit trees is done according to the spacing required for each fruit tree. They may be planted in contour, square, rectangular or hexagonal design.

5. Wind break

Trees are planted as wind breaks across the direction of the wind. Wind breaks are planted on the edges of the seasonally cropped land and in orchards.

B. Shrubs plantation

Shrubs are trees small in stature. They can be planted just like the methods used for tree plantation. Shrubs are more commonly seen in the dry and scanty rainfall areas. Shrubs are also planted along with the trees on contour bunds. Planting trees and shrubs together on contour lines at regular intervals will help the control of soil erosion considerably.

C. Grass plantation

Grasses are excellent for soil erosion control. They can be planted on the bunds, on the edges of the terraces, on the side of the mud walls, in contour strips, on the boarders of the cultivated land, as pasture lands. Grasses are excellent for reinforcing the bunds; terraces and edges of the streams and canals.

D. Others

Other biological measures employed for the soil conservation are live brush wood check, pastures, live fencing.

1. Live brush wood

Fresh and green branches of trees that can be planted by cutting are used as the vertical posts of the brush wood checks. When planted in the soil they grow like any other tree and form the permanent vertical structure of brush wood check. The branches can be planted fresh or after striking the roots.

2. Pastures

Pastures are areas where fodder grasses are grown to graze the animal. By maintaining pastures in a place we can control the soil erosion to a great extend.

3. Live fencing

Trees, shrubs and bushes are planted on boundaries of the plot to form fencing. When these fences are across the slope they contribute to the soil erosion control. Even if it is not across the slope or along the slope it will help in checking the soil erosion to some extent.

AGRONOMIC MEASURES

The soil conservation measures adopted in the cropping

systems and practices are called agronomic measures. In other words these are agronomic practices made into soil conservation measures. There are a number of the agronomic measures of soil conservation. However not all practices are suitable or practical in all the places under all the agronomic practices.

However it should be remembered that agronomic practices adopted for the seasonal cropping will not be of much use for the control of soil erosion in the long run. In other words it will be useful only for one season. After the crops are harvested there is always the chance of soil erosion if the soil erosion factors are prevalent. Therefore it is very important that for the long term soil conservation measures we should employ mechanical and biological measures strictly before we apply the agronomic measures in any place. It should be again remembered that all the agronomic practices are not suitable for all the places. In each place according to the cropping pattern and cropping system not only the mechanical and biological measures of soil conservations are to be adopted but also the agronomic measures are also to be adopted.

1. Contour cropping

When rows of the crops are taken in contour line it is called contour cropping. This method is mainly adopted for the cultivation of seasonal crops at lesser slopes though contour cropping can be practiced for perennial crops in higher slope areas up to thirty per cent slope.

2. Contour strip cropping

Different crops are grown in contour strips on .the slope. For example maize is cultivated in strip consisting of a number of lines across the slope then either on the above or-below the strip of maize a strip of arhar crop is sown.

Then any vegetable crop is sown in another contour strip. Thus we can take as many crops as we want. In this method a deep rooted crop is alternated with a shallow rooted one. Soil erosion can be controlled to a great extend by this method.

3. Mixed cropping

A number of crops are planted at random mixed or in lines one crop after another. Theoretically speaking certain amount of soil erosion control may be there during the crop- ping period.

4. Multiple cropping

Multiple cropping is a method of growing several crops in sequence on the same land during the same year. In other words in the same plot during the same year crops are grown during the kharif season followed by crops in the rabi season and zaid season. Because the land is always covered under I one crop or other the chances of soil erosion is less.

5. Multistory multiple cropping

Multistory cropping is a method in which mixed cropping of varying canopy heights are grown together. In this we can have double storey, triple storey and four storey cropping: Different crops of canopy height and width are adjusted within the same land to maximize the use of land area and the air volume area.

The principle in the multiple cropping is to plant the tallest crop in the maximum distance between which the next tall crop is planted at the middle. The next tall (third in height) crop is planted in the middle of the first tallest crop \ and the second tallest crop. The next tall crop is planted in between the second and the third.

In the multiple cropping it should also be noted that out

of the three or four crops at least two should be perennial and the rest seasonal.

The following examples will make the point clear.

a. Cocoa- banana -fodder grass for coastal areas
b. Neem -guava -pomegranate -ground nut for dry areas
c. Subabul -citrus -berseem for temperate areas
d. Sapota -guava -banana -fodder grass for irrigated areas
e. Sheesham -sapota -citrus -berseem for temperate areas
f. Drum stick trees -guava -lime -pine apple
g. Jackfruit + coconut -aracanut -clove -banana –pine-apple for humid areas
h. Aonla -custard apple -periwinkle- aloe vera for very dry areas
h. Pear -orange -plum -straw burry for hilly areas
i. Mulberry- Karonda -Banana -lucero for temperate areas
j. Date palm -casuarina -bur -aloe vera for desert areas

6. Organic farming

Addition of organic manure increases the binding capacity of the soil particles providing some sort of erosion resistance.

7. Silvi-pasture

Silvi-pasture means cultivation of trees and grasses in the same place. Due to the tree cover and the grass cover the impact of the rain and other erosion agents on the soil will be minimal.

8. Ley farming

In ley farming crops are grown in between two year duration of pasture cropping.

9. Alley cropping

In alley farming crops are cultivated in between rows of trees which are planted at suitable distance to take seasonal crops.

10. Agroforestry

Agroforestry means growing trees on land where crops are grown. The difference between alley cropping agroforestry is that alley cropping the trees are planted in lines at definite distance; whereas, in the case of agroforestry, the trees are planted at random in the gaps among the crops and in the edges and corners of the plot or land.

11. Mulching

Mulching is covering the soil surface with any biomass or sheets. By this the soil erosion is controlled in the cropping land.

12. Minimum tillage

Stirring and cultivating the soil increases the soil erosion. Therefore practice of minimum tillage is recommended "to reduce the soil erosion in the cropping land.

13. Cover cropping

Cover crops are grown to cover the soil surface and thereby reduce the soil erosion and retain the moisture in cropping land.

14. Green manuering

Incorporation of green leaves into the soil is called green manuering in general. It can be carried out in the following ways.

a. In situ

Any green manuering crop is grown on the same plot

and when they are grown up they are ploughed and incorporated into the soil. Usually legumes are grown for in situ green manuering.

b. Applying green leaves

Green leaves are brought from outside and applied on the land: The leaves may be of legumes or non-legumes.

15. Perennial cropping

Growing perennial crops like fruit and plantation crops on lands which are prone to erosion will considerably reduce the soil erosion.

16. Dibbling the seeds

Placing seeds of trees, shrubs and bushes in holes made by a peg or a stick at regular intervals in a line is called dibbling. In this method there is no need for ploughing. Similarly we can dibble seedlings also.

17. Planting potted plants

A number of crops (trees, pulses, vegetables, oil seed crops) can be grown in pots or polybags in nurseries. They can be planted in the field along with the mud balls

16. Spot planting

Spot planting means sowing seeds or seedlings on spots at proper and recommended distance. Only the spot is prepared in the round or square form leaving the rest of the area untilled. Planting of gourds is done in this manner.

17. Growing on pandals

Growing creeping, climbing and spreading crops on pandals helps in soil erosion control as the pandals form a barrier to the rains.

18. Alternating deep rooted with shallow rooted

Crops with deep roots are grown during rainy season during which time soil erosion occurs more easily and planting shallow rooted crop during the dry season.

Concluding remarks

Soil is the source of all our requirements in life. Erosion of soil is erosion of human life and finally destruction of forms of life from the face of the earth. Soil should be preserved by all means and preservation of soil should be every body's concern. However, most people have very little idea about the various means of the preservation of the soil.

This booklet enumerates and describes briefly all possible types of soil conservation measures. Some of them are not found in any of the literatures as they have been compiled from the field experiences of various people including one's own. However it should be remembered that all these measures will have to be applied in combination and not in isolation.

Though mechanical erosion measures are costly without mechanical measures we cannot implement effective soil erosion control on the steep slopes, stream banks, gullies, in the rivers, streams, sides of roads and canals. However along, with mechanical measures we should always incorporate the biological and agronomic measures to improve effectiveness of the soil erosion measures adopted. Also biological and agronomic measures are income generation for the community.

Chapter-13

Impact of Agriculture on Environment

Since independence, agriculture has been the most important human involvement in India with majority of the population engaged in it. Increasing demands for agricultural products both for the home consumption and export continue due to an increasing population both within the country and in the world. However, questions arise whether the present system of agriculture is environmentally sustainable or not. There are many concerns about depleting water resources, soil fertility losses, air pollution etc. In this chapter an attempt is made to high-light the environmental impacts resulting from existing and emerging agricultural production technologies. The main aim and purpose is to provide information useful in precluding environmental deterioration while allowing for the necessary expansion of agricultural production.

Ever since, the emergence of green revolution, agriculture has become the most productive enterprise in the country, and the demands for increasing agricultural productivity are expected to continue due to an increasing population. However, the current problems and indicators of longer term concerns relative to agricultural productivity include the declining growth rate in agricultural productivity; shortages of resources like energy, water and soil and increasing concerns about deterioration of

environmental quality due to pesticide and fertilizer usage and soil erosion. Hence, the need of the hour is to continue to produce an abundance of food and fibers to meet the growing demand of the population at reasonable prices and at the same time, the quality of environment and the scarce natural resources should also be conserved. For this new technologies must be developed to look into the agricultural production system.

ENVIRONMENTAL IMPLICATIONS OF TRENDS IN AGRICULTURE

Few environmental implications related to types of agricultural activities are being mentioned here.

A. Effects of pollutants, from agricultural activities

Major pollutants from agricultural activities which include sediments, plant nutrients, heavy metals, salts, bio-degradable organics, pesticides, pathogens, odours and ubiquitous dusts, pesticide residues may contaminate surface waters, ground water, soil, the earth's atmosphere and thereby, affect the health of human beings through food chain. Pesticides reach water through direct surface run-off, ground water seepage, and aerial drift during application and by being deposited in waters upon volatilization. However, surface run-off pesticide concentrations depend upon the pesticide solubility, soil type, application techniques, quantity applied, and the amount and timing of rainfall.

It has been seen that the agricultural residues of nitrogen and phosphorus enter into the surface and ground waters from run off and leaching losses and from movement of sediments into surface waters, The total amounts of the nitrogen and phosphorus that can be lost from agricultural lands depends upon a number of factors. For instance, for

the crop land, these include application rates, soil properties, terrain, soil erosion tendencies, crop management practices and the amount of rainfall. Soil sediments enter into water from all agricultural segments, and it is a transport agent of heavy metals, pesticides and plant nutrients. Any practice that increases or reduces sediment transport, affects the heavy metals transport accordingly. Slope and cover crop cultivation practices influence the amount of sediment lost. Soil salinity which results from irrigated crop practices, as well as the salinity acquired as inherent quality of the soil affects the quality of ground water and surface water, and soil productivity.

It is important to note that the potential environmental effects of pollutants from agriculture often cannot be assessed separately. Various other sources of pollutants are present within the common environmental receptors like, streams, rivers; lakes etc. Consequently, synergistic pollutant effects occur and associated environmental implications may result. By volume, sediment is the major pollutant in surface water, and it is also the transport agent for other residues. Sediments obstruct the drainage and irrigation canals, fills the reservoirs and lakes, and creates turbidity. Therefore, it is an economic issue, to clear the canals and reservoirs that have deposition of sediments. The surface and ground waters show increased salinity from irrigation practices. However, there is no danger to human health from increased salinity in surface waters. Its control also is primarily an economic issue since it involves industrial water treatment costs. High salinity levels can result in unpleasant taste and hardness, and a loss of aesthetic quality.

Salt build up in ground water can reduce crop yields, and crop production can become economically infeasible in areas of toxic salt levels. Increased levels of nitrogen

com- pounds and phosphates in surface waters may lead to excessive algae growth which then increases the dissolved oxygen in water. The resultant stagnation in shallow water can cause increased mosquito populations and their consequent threat to health, a decrease in fish populations and other aquatic life, an overall decrease in animal and human water use and taste and odours. If there is a movement of ground water containing high concentrations of nitrates into well waters, then is a major direct threat to humans from nitrates. In this reference, it is important to note that the US public health service has set 10 mg of nitrate expressed as N per litre as the upper safety limit. But many wells as well as some surface water bodies, exceed these limits. It is of primary concern that both persistent and non persistent pesticides may be found as residues in soil. Persistent pesticides may remain chemically active in the soil for several years, whereas non-persistent pesticides disappear within a few months of application. Primary concern is the uptake of soil pesticides by the crop which in turn can contaminate the foods.

B. Baseline situation for non-irrigated crop production

For assembling the basic information on non irrigated crop production, it is important to measure the soil erosion by estimating the average annual rates of soil movement from the crop land. Erosion losses from cropland may vary from negligible to more than 100 tons per acre. Nutrients are transported to surface waters largely by two means. One is nitrogen which is relatively soluble, reaches surface waters via run off and percolation. The other is phosphorus; relatively insoluble gets attached to sediment and enters the water through sediment movement. Although commercial fertilizer is the major source of nitrogen to crop lands for

supplying over a million ton annually), animal wastes (manure) also contribute significant quantities of nitrogen. Animal wastes can pose more significant local N and P pollution problems than commercial fertilizers where per acre application rates are high. Since manure is disposed off on cropland in the vicinity of the feed lot) in which it was produced, the greater threat of pollution will be concentrated in the major livestock producing areas.

Even minor quantities of pesticide pollutant') create great concern because of their potential toxicity and persistence. Very little data or information exists on pesticide loading from crop land in surface waters. In addition to this, no estimate has been made about the total amount of pesticides entering the nation's streams and rivers; however, investigations are being made with regard to run off water quality in local areas.

C. Environmental implications of trends in non-irrigated crop production

The primary implications of environment on the trends in non-irrigated crop production must be known.

1. Crop management trends

The main trends that can be projected in crop management involve conservation tillage, crop sequence, and seed/plant improvement. In conservation tilling, the increased utilization of no tillage and reduced tillage practices will have the following major impact on both water and soil quality.

(i) The reduction in soil disturbance and the greater cover of residue on the cropland will impede soil erosion by reducing run off and this in turn will reduce the sedimentation of the surface water.

(ii) Although direct run off can be expected to decrease, percolation and leaching will increase since a greater part of the moisture will be retained on the cropland.

(iii) With the increased utilization of conservation tilling a greater infestation of cropland by insects and diseases will occur, as a result of this increased application of pesticides will be required and will result in a greater potential for pesticides run off.

(iv) Although, total run off will be reduced, the nitrogen concentration in that run off may be increased.

(v) Conservation tilling may also result in increase of nutrient run off both because of the large amounts of organic matter in the cropland and the possible greater applications of fertilizers.

(vi) The increased percolation will increase the potential for nitrates entering the groundwater and,

(vii) Due to the reduction in sedimentation, movement of phosphorus to surface water will be substantially decreased.

Hence, in the context the above mentioned points, the overall implications of conservation tillage will be a reduction of the potential for surface water pollution, however, the groundwater pollution potential will increase.

The trends in crop sequencing carry diverse implications. The mono-cropping and no meadow (meadow is a grassland especially used for growing hay) rotation practices would tend to increase water and land pollution. Mono-cropping increases the threat of insect and disease infestation, hence pesticide applications may increase. In addition, mono cropping depending upon the type of crop involved, may increase or decrease erosion. Reducing the meadows from rotation sequence would

increase erosion potential and typically require increased fertilizer application. Both of these would contribute to water and land pollution. Although crop sequencing practices would affect the environment adversely, relay and double cropping may have indirect beneficial effects. Both of these practices may impede erosion and reduce, in many cases, fertilizer requirements of a unit on output basis, i.e. hence, more intensive double cropping on one location may be preferred to extensive cropping on multiple areas. However, slight increases in insecticidal requirements would increase the potential for pesticide run off.

However, the environmental effects of seed/plant improvements are largely indirect. These genetic developments primarily affect crop yields and such increases have minor impacts on any given acre of cropland. The most significant implication stemming from increased yields would be a decrease in the cropland required to meet a specific level of demand. Although the overall cropland requirements will continue to increase, that increase would not be as great as it would have been without the improved crops.

2. Soil-water management trends

Trends in soil-water management include practices designed to reduce run-off and soil erosion, to enhance the moisture storage capacity of the cropland, and to decrease wind erosion. Erosion control- measures such as contour farming, terracing and use of winter cover crops are traditional methods of stabilizing the soil. Their use should be continued since, they are recognized to be environmentally sound and they benefit the producers. The principle feature of these practices is that they impede run-off and retard sediment movement and thus reduces both water and land pollution. A secondary effect is that they increase the moisture retention capacity of the soil and they

increase percolation. This increased percolation results in a greater potential for nitrates entering the ground water.

Two trends that are significant for moisture conservation in the soil are fallow cropping and utilization of agents which reduce evapo-transpiration. Fallowing is common in semi-arid areas where rainfall is insufficient to produce a satisfactory annual crop. It not only promotes nitrification, but it aids in controlling noxious weeds. Additional benefits of fallowing are an increase of soil moisture and a slight decrease in the requirements for nitrogen fertilizer and herbicides. An adverse effect is the increased potential for both wind and soil erosion, particularly when fallowing is accomplished with cultivation. Evapo-transpiration reduction agents increase soil moisture and thereby significantly increase the crop yields in moisture deficient areas. The effect on the environment is similar to that of increasing crop yields through improved crops. The impact is indirect. Increased requirements for croplands are slightly reduced because of the greater production levels resulting from decreased evapo-transpiration.

Although wind erosion is most severe in semi-arid and arid regions under irrigation, it is significant in non-irrigated croplands. Reducing wind erosion not only stabilizes the soil and reduces its pollution and erosion; it also controls sediments movement by active surface water movements. These effects also reduce the potential for air and surface water pollution.

3. Nutrient management trends

Nutrient management trends with environmental implications include new methods of applying fertilizers alternative nutrient sources, biological nitrogen fixation and certain technological developments. Alternative methods

of commercial fertilizer application are generally more efficient and cause less soil disturbance during application. However, multiple applications are designed to apply fertilizers on cropland during favourable conditions of nutrient uptake by plants. However, multiple applications if increased even to a small extent may cause soil disturbances resulting in increased soil erosion. The major benefit is that the fertilizer remains in the soil a longer period of time before being utilized by the plants and is subject to greater risk .of loss through run off or leaching.

Biological nitrogen fixation development is a means of increasing nitrogen fixation by plant micro organisms, and methods of improving symbiotic relationships between plant and micro organisms. Also some genetic developments are anticipated in introducing nitrogen fixing capabilities into non-legume plants requiring high applications of fertilizers. With such nitrogen fixation developments considerable reductions in fertilizer usage would occur, and this would further reduce potential nitrogen run off and leaching. The collective trends in nutrient management (other than increasing the use of fertilizer) are expected to have an overall beneficial effect on the environment.

4. Pest control trends

Trends in pest control include improved methods of application, developments in new pesticides, resistant varieties and biological control. Improvement in the methods of applications are expected to have beneficial effects, e.g. improvements in aerial applications techniques will decrease the amount of pesticides applied to non-target areas, with a con-sequent reduction in pesticide usage and a greater efficiency of applications.

Development in dual application of fertilizers and

pesticides will have both favourable and unfavorable environmental implications. Development of more resistant varieties is expected to reduce the requirements for pesticides. The most beneficial developments are anticipated in the area of new improved resistant varieties to pests such as insects, nematodes and birds, plus diseases. Biological control developments will also influence pest control practices. Potential developments involve the use of juvenile hormones, pheromones, sterile males, predators and parasites. Both beneficial and adverse environmental effects may occur with these developments. Biological control in some cases would decrease the requirements for pesticides on specific crops. However, this would reduce potential pollution problems, but the introduction of these biological control methods can have potential damaging effects on the environment if they affect the non-targeted plants or beneficial insects.

D. Baseline situation for irrigated crop production

It can be stated that significant pollution problems can occur in both surface water (streams and rivers) and ground water by pollutants from irrigated croplands. The major surface water pollutant (by volume) is sediment resulting from soil erosion. While soil erosion is not a major concern in irrigated crop land, the sediment produced can also carry other pollutants such as pesticides and fertilizers. Fertilizer pollution problems can be expected to occur in those geographical areas having considerable cropland acreage receiving high rates of application. Irrigation return flow salinity can be a significant pollutant to surface water and ground water and the composition of soil. The major components of salinity include water soluble compounds of the cations of calcium, magnesium, sodium and of the anions carbonates, bicarbonates, sulfates and chlorides.

Minor amounts of iron, aluminum, manganese and other cations are also present. Salinity may occur during normal irrigation practice also as a portion of the irrigation water is carried to the subsoil or ground water. This percolating water carries with it salts accumulated in the root zone. Some may be eventually collected by drains and returned to the main stream. The salt concentration of the irrigation return water may be more than that of the initial irrigation water. Another fraction accumulates on or near the surface. Salinity problems are associated principally with cropland irrigated with surface water.

E. Environmental implications of trends in irrigated crop production

The points mentioned for non-irrigated cropland are also applicable to the trends that are seen in irrigated cropland management practices such as crop management, soil water management, nutrient management and pest control. Only the points relative to the irrigated cropland will be mentioned here.

Reduced water application during irrigation has both beneficial and adverse effects on the environment. The primary benefit involves the conservation of water resources. Adding excessive moisture during irrigation not only wastes water, which is scarce in supply, but also may damage the crop. On the other hand recycling may increase problems of salinity. However, direct monitoring of irrigation requirements is a prerequisite for the proper management of later practices concerning reduced irrigation.

ENVIRONMENTAL EFFECTS OF CONSERVATION TILLAGE PRACTICES

Tillage refers to the preparation of land for planting. The purpose of this practice is to establish a weed free seed

bed that permits the incorporation of fertilizer, uniform seed placement, quick germination and a good early growth rate. For years, the usual/standard tillage method followed has been to turn the soil completely along with residues just before planting. Tillage that completely inverts the soil and buries all crop residues generally will leave the land much more exposed to the erosive forces of wind and water than tillage that twins the soil-less and leaves more crop residue on the surface. This latter type of technology is called conservation tillage.

Conservation tillage is a system which covers a variety of tillage practices, but they all have three features in common.

i. They use some implement to prepare the seed bed.

ii. They leave enough crop residues on the soil surface to significantly reduce erosion.

iii. They rely less on cultivation and more on herbicides to control weeds than conventional tillage method.

Conservation tillage proves to be very effective in the control of wind and water erosion. Soil erosion by wind can be a problem wherever the following conditions of soil, vegetation and climate prevail. These conditions include; i) a soil that is loose, dry and reasonably divided; ii) a smooth soil surface on which vegetative cover is absent or sparse; iii) a large enough field; and iv) wind that is strong enough to move soil.

Conservation tillage is effective in wind and water erosion control since the presence of crop residues on the soil surface presents a barrier to wind and retards run off. The formation of larger soil clods that occurs during conservation tillage systems serves as a barrier to wind and water movement. This capacity to reduce erosion is

one of the most important features of conservation tillage technology. Conservation tillage is found to be very effective in reducing sediment in run off water. This also has influence on pesticides in run-off water. Some pesticides either are not very soluble or they adhere tightly to soil particles. In these cases, erosion reduction prevents or greatly reduces entry of pesticides into surface waters. Thus, conservation tillage act to lessen the impact of such pesticides, and also' they reduce run off but do not eliminate it. Therefore, because conservation tillage has such an increased reliance on pesticides particularly herbicides, it is a greater threat to the environment than conventional tillage as far as pesticide damage is concerned. This is particularly possible in soil clays in wet tropical regions where such soils do not bind the herbicides to their surfaces. In such environments, a large portion of the herbicide can be carried into water bodies.

Environmental Effects of Organic Farming

Organic farming can be defined as a production system which avoids or largely excludes the use of chemical fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent possible, organic farming approach derives maximum benefit through crop rotations, crop residues, animal manures, legumes, green manures, off farm organic wastes, mechanical cultivation and aspects of biological pest control. All these practices contribute towards maintaining soil productivity and tilth, supplying plant nutrients, and con- trolling insects, weeds and other pests.

Environmental benefits and opportunities that lend support to organic farming practices include reduced soil erosion, reduced nutrient and pesticide pollution, reduced energy requirements, increased recycling of organic wastes

and enhanced soil and water conservation. These are mentioned here briefly.

i. Reduced soil erosion

Practices involving the use of cover crops, green manure crops and organic matter management all help to control soil erosion. However, the advantage of organic farming methods is for controlling soil erosion over that of chemical intensive systems.

ii. Reduced nutrient pollution

Organic farmers avoid or restrict the use of commercial fertilizers and instead rely more on recycling of nutrients in their farming operations. This reduces the opportunity for residual nutrients in soil which might be subjected to leaching. Reduced soil erosion also minimizes nutrient transport from fields.

iii. Reduced pesticide pollution

Organic farmers greatly restrict or avoid the use of pesticides in their operations. Decreased use of pesticides helps to reduce run off if the agricultural chemicals in some areas and to reduce the spread of chemical residues in the environment.

iv. Reduced energy requirements

Organic farmers use appreciably less total energy for producing most crops than conventional farmers. Considerable quantities of energy are saved on organic farms by the use of crop rotations and the application of organic wastes in place of chemical fertilizers especially nitrogen.

v. Increased recycling of organic wastes

In addition to the recycling of on-farm organic wastes, some organic farmers utilize off-farm sources of organic

wastes, including sewage sludge and processing wastes, thereby achieving a higher crop yield potential. This helps to resolve a disposal problem, while contributing greatly to improved soil productivity.

vi. Enhanced soil and water conservation

Organic farmers make extensive use of crop and soil management practices that effectively protect the soil and improve infiltration. Improved water conservation with organic farming may provide opportunities for farmers in dry-land areas.

IMPACT OF AGRICULTURE ON WATER AND SOIL

Technologies used for various agricultural activities can have significant impacts on both water (surface and ground water) and soil environments. Here an attempt is made for brief summarization of these impacts based on current practices used. Identification of water and soil impacts include information on nutrient pollution of surface and ground water, pesticide pollution of surface and ground water, sediment losses and soil erosion and general ground water concerns. Due to the importance of the soil environment relative to the nature and extent of both water and soil impacts, it is essential to first give a brief background information on this environmental media before actually dealing with the information regarding environmental impacts.

A. Nutrient pollution of surface and ground water

Soil contains large densities of bacteria that decompose soil organic materials and form an integral part of the soil organic composition. Bacterial densities in soil range from several thousands to 200 million bacteria per gram of soil. Nitrogen and phosphorus resulting from fertilizer applica-

tions and other agricultural practices can contribute to both surface and ground water pollution. Surface water contributions are considered to occur from non-point source discharges which primarily occur during rainfall where run off from the land surface carries sediment, pathogens, sediment adsorbed chemicals, dissolved chemicals (such as nutrients and pesticides), heavy metals, and easily oxidizable organics into adjacent water ways. Dissolved chemicals may also percolate through the soil to interflow regions and or ground water, and be discharged in sub-surface flows. Nutrient pollution of ground water involves sub-surface transport to water bearing zones. The transport and fate of nitrogen in the sub-surface is dependent upon the form in which nitrogen enters and various biological conversions which may take place. Figure 1 displays the forms and fate of nitrogen in the sub-surface environment.

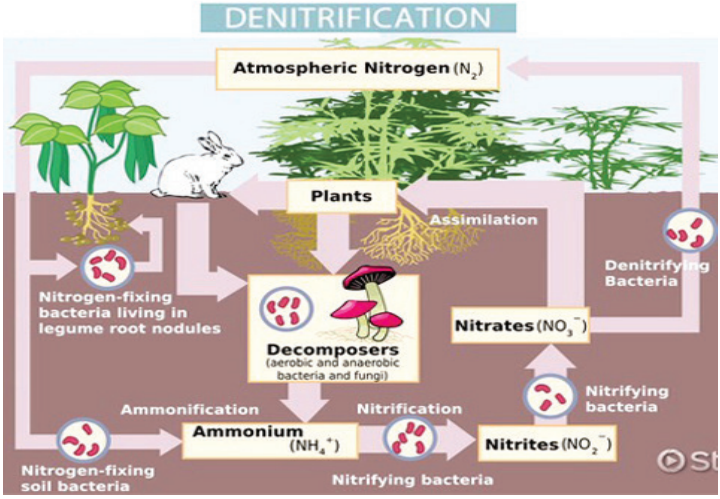


Fig 1 Nitrification

Nitrates (N03) can be formed by nitrification involving ammonium ion conversion to nitrites and then to nitrates. Nitrification results from an aerobic reaction performed primarily by obligate autotrophic organisms and NO3 is

the predominant end product. Nitrification is dependent on the aeration of the soil, which in turn is dependent on soil characteristics, percolation rate, loading rate, distance to impervious strata and distance to ground water. However, complete nitrification may occur in more clayey soils such as silt loams and clays.

Denitrification is another important nitrogen transformation in the sub-surface environment. It is the only mechanism by which the NO3 concentration in the percolating (and oxidized) irrigation water can be decreased. Denitrification, or the reduction of NO3 to N2O or N2, is a biological process performed primarily by hetero-troths. In the absence of O2, NO3 acts as an acceptor of electrons generated in the microbial decomposition of an energy source.

Based upon the forms of nitrogen in fertilizer applications, and the biological transformations which can occur in the sub-surface environment, there are two forms of major concern relative to ground water pollution ammonium ions (NH4) and nitrates (NO3). Ammonium ions can be introduced directly from fertilizer applications, or they can be generated within the upper layers of soil from the ammonification process (conversion of organic nitrogen to ammoniacal nitrogen). The transport and fate of ammonium ions may involve adsorption, cation exchange, incorporation into microbial biomass, or release in to the atmosphere in the gaseous form. Adsorption is probably the major mechanism of removal in the sub-surface environment

B. Pesticide pollution of surface and ground water

Pesticide usage has aided in increasing agricultural productivity but this potential may prove detrimental to

health and environment. This include the destruction of non-target organisms; deposition of residues that magnify in food chains and eventually injure predatory animals at the top, including man; and direct health effects on pesticide users. The chief concern related to the impacts of pesticides on the natural environment is associated with the fact that pesticides can be transferred from their original application sites to other locations by erosion, drift run off and biological means.

Figure 2 illustrates the pesticide cycle in the environment and its examination reveals numerous transport mechanisms that can lead to surface and ground water pollution, soil pollution and air pollution.

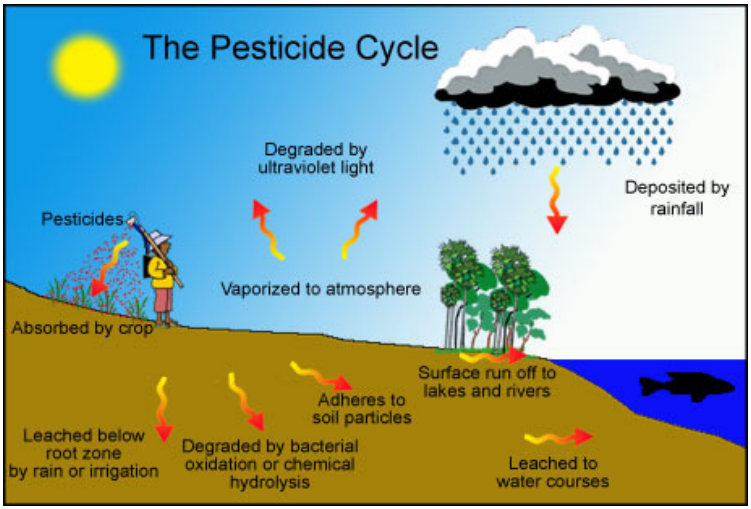


Fig 2 Pesticide Cycle

The transport and fate of organic contaminants in the sub-surface environment is a relatively new area of concern, and hence enough literature regarding this is not available. A variety of possibilities exist for the movement of organics, including transport with the water phase, volatilization losses from the soil system, retention from the soil due to

adsorption, incorporation, microbial or plant biomass, and bacterial degradation. However, the relative importance of these possibilities in a given situation is dependent upon the characteristics of the organic, the soil types and characteristics, and the sub surface environmental conditions.

C. Sediment losses and soil erosion

As a result of heavy demand for an increase in agricultural production, there have been instances of inclusion of marginal lands into production and removal of soil erosion control structures. When this is combined with the use of heavy dose of chemical application, the stage may be set for soil erosion problems. Soil erosion has been of concern since it can cause de- crease in soil productivity and increase in water and air pollution. Soil erosion lowers soil productivity through the loss of storage capacity for plant available water, loss of plant nutrients, degradation of soil structure and decreased uniformity of soil conditions within a field. Loss of top soil nearly always reduces the inherent productive potential of a soil. The characteristics of individual soils, however can strongly affect the quantitative impact of soil erosion upon productivity.

D. Nutrient management practices

Nutrient losses through the run off water are primarily a result of fertilizing practices. The use of chemical fertilizers to supplement the nutrients supplied by the soil has long been recognized as necessary in most soils for optimizing crop yields and plant quality and reducing erosion by increasing vegetative cover. The potential for pollution from fertilizers will generally be highest where large acreage are treated with heavy doses of fertilizers. However, the nutrients are moved from agricultural land by leaching, direct run off and in association with sediment from erosion. A number

of practices will reduce direct run off and erosion and, thus, reduce the nutrient transport. However, in some cases, such as leaching, additional or alternative practices will have to be used to achieve the desired degree of control. These practices involve changing the use of nutrients, for instance, these may include eliminating excessive fertilization, timing the nitrogen application, using crop rotations, using animal wastes for supplying nutrients instead of ploughing under green legume crops, incorporating surface applications, controlling surface applications and using legumes in hay lands and pastures.

E. Pesticide management practices

The use of chemicals to control the crop pests has been on an increase. Investigations reveal that some chemicals are highly toxic to fish or other aquatic fauna and can persist in the aquatic environment for a long time, so that even very low levels of these pesticides in run off may be of environmental concern. On the other hand, many agricultural chemicals are not acutely toxic to animal life, do not persist from one crop season to the next, and do not accumulate in food chain organisms; consequently they may be used at normal application rates without fear of causing unacceptable environmental damage.

Some of the methods that can be adopted to minimize the pesticide application in agricultural practices include:

i. adoption of production techniques which do not use pesticides,

ii. use of alternative pesticides that are not water soluble,

ill. optimization of pesticide formulation,

iv. reduction in excessive treatments,

v. optimization of the time of day for pesticide application,

vi. optimization of the dates of pesticide application,

vii. use of optimum pesticide application rates and

viii. management of aerial applications.

Besides all these measures, a reduction in run off or erosion will also reduce loss of applied pesticides, and practices that control run off and erosion should always be considered in pesticide pollution control.

IMPACT OF AGRICULTURE ON AIR QUALITY

Agricu1tural practices can have significant impacts on the air environment. In addition to the impacts of agricultural technologies on air quality, which may largely result from non-agricultural activities, can exert undesirable effects upon agricultural crops and animals. These impacts of agriculture on air quality based upon the usage of some emerging agricultural technologies are in terms of tillage operations used, air pollutants obtained from open burning, from wind erosion, from unpaved roads, from agricultural vehicles used in fields, pollutants obtained from harvesting and grain handling and pollutants tram pesticide applications.

During a tilling operation, dust particles from the loosening and pulverization of the soil are induced into the atmosphere. Open burning of crop residues, as well as debris from land clearing operations, represents a potentially significant source of air pollutants from agricultural activities. Ground level open burning is affected by many variables, including wind, ambient temperature, composition and moisture content of the debris burned, and compactness of the pile. In general, it can be said that the relatively low temperatures associated with open burning increase the emissions of particles, carbon mono-oxide, and hydrocarbons and suppresses

the emissions of nitrogen oxides. Particulate emissions represent the primary type of air pollutant resulting from wind erosion. Factors influencing particulate emissions from wind erosion include soil type, precipitation patterns, exposed area and wind speed.

Vehicles used for the agricultural operations include tractors, cars and trucks. The types of air pollutants emitted from such vehicles include carbon monoxide, hydro carbons, and nitrogen oxides. Harvesting and grain handling can produce large, quantities of particulate and hydrocarbon emissions. Further, substantial quantities of pesticides can become air-borne during and following the aerial spraying operations. The key mechanisms for pesticide introductions into the atmosphere include aerial drift and evaporation (volatilization) from soil and plant surfaces. Volatilization is a major pathway of loss of pesticides from soil, and loss is greater from moist than from dry soils. The relative amounts of a given pesticide entering the air and surviving to some downwind site depend on the nature of the source (eg., the type of application in agricultural operations), its physical properties and chemical reactivity, its form once it enters the air, and that which exist throughout the process. One concern pertaining to air borne pesticide residues is related to potential human health' effects, particularly for agricultural workers.

A. Air pollution effects on crops

In order to understand the effects of air pollutants on agricultural crops, it is necessary to consider the basic structure of plant leaves and the functioning of the various components of the structure. The major plant processes that occur include photosynthesis, transpiration and respiration. Several components of the leaf structure are involved in the photosynthesis process. The leaf veins are

involved in moisture and nutrient transport to the leaves from the soil and root system of the plant. The effects of air pollutants on crops must be considered, in terms of environmental factors including temperature extremes, excess water, water deficiency, nutrient deficiency and bacterial or viral disorders.

High temperatures may cause chlorosis which is reflected by yellowing of the leaves, while low temperatures may also cause chlorosis or necrosis. Excessive water can damage veins of the leaves, and lead to plasmolysis, while a water deficient condition is reflected by necrosis. Nutrient deficiencies to plants can cause chlorosis or necrosis, while bacterial and viral disorders may be manifested by plasmolysis. In brief, it can be said that many factors influence the visible response of a given species of plant to a particular pollutant. Among the more important are the age and variety of the plant itself, the concentration of the pollutant, the length of exposure, the vigor of the plant and growing conditions before, during and after exposure. Thus, the environmental factors can act as potentiates for the specific air pollutants in terms of effect, or they can cause some typical symptoms, specific to the type of the pollutant.

B. Air pollution effects on animals

Under both acute as well as chronic conditions, air pollutants can affect the animals significantly. In terms of chronic effects, the air pollutants which have received the utmost attention include fluorides, arsenic and lead. Air borne fluorides have caused more world wide damage to domestic as well as farm animals than any other air pollutant. The animals most affected by fluorides include cattle and sheep, and fluoride damage to animals have been of great concern. The symptoms of fluorosis in cattle are a

function of whether or not there is an acute exposure or a chronic exposure. In general, the acute symptoms may include lameness, stiffness, lack of appetite and thirst, diarrhea, muscular weakness and possibly death.

The chronic symptoms may include skeletal changes, lethargy, emaciation, poor health, and possibly a poor reproductive efficiency.

Fluorosis can result from drinking water with high fluoride contents which may affect the human being as well as animals. However, this is possible that in some cases diseases and symptoms as indicated above, can occur from factors other than exposure to atmospheric fluorides. Some other examples of air pollutants which have exhibited effects of domestic animals include ammonia, carbon monoxide, hydrogen sulfide, sulfur dioxide and nitrogen oxides. There is some evidence that ammonia can have harmful effects on poultry, carbon monoxide can affect quite a number of animals and dusts can also affect rabbits, hydrogen sulfide can affect poultry, sulfur dioxide can affect cattle and sheep and nitrogen oxides may also affect quite a number of farm animals.

Chapter-14

Planting and Management of Trees

Introduction

The trees referred in this chapter title belong to mainly four types: forest trees, fruit trees, plantation crop trees and ornamental trees. Trees are long living plants and they remain in the same place for many years. They have comparatively deep and wide spreading root system. Their root zone areas will get exhausted of all the plant nutrients within a year or two; hence regular yearly manuering should be done to make the trees grow and produce desired results. To establish well any of the trees especially the fruit and plantation crop trees require deep and wider pits (minimum 4:4:4 ft) dug at least one year ahead and is left exposed to all the seasons of the year of the place for seasoning of the pits. In hard and less fertile soil the pits should be deeper. While digging the pit the top soil and the bottom soils are kept separately. Very small water channels directed towards the pits should be made so that during the rainy season the surface flow water can be collected into the pits which will penetrate into the deeper layers of the soil facilitating many physico-chemical and biological changes in the bottom soil of the pits.

During the course of one year when the pits are left open for weathering, seasonal intercrops of pulses, vegetables, bananas and papayas can be taken. Such seasonal crops can be taken if marking of the pits are done

by strong pegs of two to three feet are driven down strongly in position. Therefore sooner after digging of each pit, the weeds and thinned out (removal of excess number of crop plants or plant parts) crop plants around each pit can be placed into it. Such intercropping can be more easily done in fruit trees plantation than forest trees plantation because forest trees are planted at closer distance and hence the space for intercropping is very limited. If bananas and papayas are planted the left over plant parts would be rich in moisture which at the time rotting will be released into the bottom soil of the pits as they go through the decomposing process. They should be chopped into pieces before they are deposited into the pits. If possible place a kilo or two of raw cow dung or any other animal dung into the pit over the green vegetation placed into the pits. For easy availability of animal dung, during course of land preparation and digging of the pits, meat or milch animals may be reared in the planting area. They will convert all the prunings and trimmings into valuable dung. Similarly all the subsequently growing weeds or crop wastes are either fed to the animal to produce much valuable dung to be used for manuering of the pits or the planted sapling or seedlings later. The banana and papaya stems and other parts should be chopped into small pieces to facilitate easing rotting. Place the green leaves first and over that place the animal dung. During the rainy season they will rot and give rise to proliferation of millions of macro and micro-organisms penetrating into the bottom soil and a number of desirable physico-chemical and biological soil changes take place at the bottom of the pits which will be highly beneficial to the would be planted saplings or seedlings.

In the same way all the crop wastes may be composted in locations of the planting area to generate well rotten compost. If grass and other vegetative growth is abundant

cattle, buffalos, sheep and goats may be also reared during the year of the seasoning of the pits. It will facilitate the spread of the root system of the future plants. Deeper and well spread root system will contribute greatly to the health and longevity of the trees planted. The saying "Well begun is half done" will be made literally true in such kind of pit preparation for tree plantation. At present, most of the plantations have failed mainly due to the neglect of these initial aspects of land preparation for tree plantation. Most of the *Vana-mahotsavas* in our country are mere annual rituals without even thinking of any desired result.

After one year of gestation or seasoning of the dugout pits, they are filled up to at least three fourth level with a mixture of well prepared compost and topsoil at the rate of 1:1 ratio and leave it for few more months before planting poly-bag grown two year old, budded or grafted healthy and vigorously growing saplings of fruit trees. For afforestation, though the pits are of less size the depth could be increased on slopes or in less fertile and hard soil. On the slopes the depth of the pit is measured at the lower side of the slopes. Even for afforestation at least one year old or one meter high vigorously growing polythene-bag- raised seedlings of saplings should be planted.

Tree plantation programmes will be successful only if proper Planning, Planting and Management (PPM) of the trees are ensured. All the energy, time and resources spent for raising the plants in the nursery will only go waste unless the plant survives and grow into a healthy and more productive tree. Success of any tree plantation depends on 1) how good the pits are taken 2) how good a sapling or seedling is planted and 3) how well they are taken care during the first five years. If any of the plants are not growing proper during first three years replace them with vigorously

growing plants. For this one should always have 10-15 per cent extra plants stocked in the nursery maintained in the plantation area itself.

There are two types of forestry plantations: (1) Social Forestry and (2) Conservation Forestry. Social forestry is established on a village land or on forest land close to the villages which were earlier depending on the nearby forests. Since forests are dwindling and also new forest laws restrict the entry of the people into the forest for collecting minor forest products the idea of social forestry was promoted. But most of the social forestry programmes became a failure due to lack of proper planning for planting and management of the seedlings or saplings planted.

SOCIAL & CONSERVATION FORESTRY

Social forestry, as it is generally understood today, is a special programme of planting trees with the basic objective of meeting the day to day requirements of the rural poor mostly landless. The requirements of these poor people include firewood, fodder, green manure, small timber, fruits, oil seeds and a few more other forest products. But in **conservation forestry** the environmental aspects like conservation of soil and water and maintenance of bio-diversity etc. are emphasized. Depending on the soil types all the areas above 33.3 to 50 per cent slope should be placed under perennial forests with a sole view of conservation objective. How much of the area between 33.3 to 50 per cent slope should be under perennial forest is determined by the type of soil: in higher rainfall area or in sandy-rocky soil the perennial nature of the forest should start at 33.3% slope, whereas for more of deeper clay soil the perennial nature of the forest need to be begun by 50% or 45 degree slope and above. In highly erodable soil also perennial conservation forestry plantation should begin from 33.3%

slope. However proper planting is only the initial operation of any afforestation programme. The more important work is to ensure the survival of the saplings planted. For this the plants are protected and cared till at least five years or it grows to a height of 5-6 feet with a thick and strong trunk or stem. Mindful of the saying **"Look after the seedlings for the initial five years, then the trees** will **look after you".** A well maintained orchard (fruit trees planted in a sizable area) becomes a perennial source of income for many years.

For raising successful plantations, selection of suitable sites and choice of right species are very important. If the objective is to raise different economically useful species for social forestry, sites have to be selected that would match the chosen species. On the other hand, if a particular site has to be planted and made into an economically useful area, right species of fruit trees have to be selected which are suitable to the selected site. To make these plantations successful, one should have the basic knowledge about planting and caring of saplings and seedlings. Otherwise as is happening in most part of India and abroad, social forestry and other type of tree plantation areas remain barren lands after two or three years of tree plantation and the celebration of "*Vanamahotsava*" becomes an endless yearly rituals lead by politicians and social activists resulting in very poor survival of the plants wasting all the efforts and money.

WHERE TO PLANT?

Whenever forestry programme is suggested people immediately raise the question, "where to plant, we have no land". Often they are unable to identify all the possible locations of tree plantation. But a thoughtful assessment will reveal a number of possibilities. Given below is an enumeration of all possible locations grouped under two heads: (1) uncultivated (2) cultivated.

A. Uncultivated lands

1. Common land: village, panchayat or government,
2. Pasture lands: in rows 15-20 meters apart in east-west direction which will allow fodder grasses to be grown,
3. Road sides: village and panchayat roads, State and National Highways,
4. Stream and river banks: trees should be planted in long parallel strips on both sides in long strips as wide as the stream/river; this will prevent stream bank erosion as well as be a protective layer for the river or stream on both sides,
5. Both sides of common canals, streams, etc.,
6. Permanent fallow land: cultivable land lying idle for more than two or three years,
7. Barren land: unfertile land,
8. Rocky land: land with huge boulders and rocks,
9. Gravelly land: laterite soil,
10. Sandy soils/lands: seashores, desert areas,
11. Sides of ponds: private or common,
12. Immediate surrounding of percolation tanks: on the bunds and lower catchment area/upper sides of a tank,
13. Sides drainage channels,
14. Sides of railway lines,
15. Eroded land: by water or wind,
16. Ravines, gullies, seasonal water courses,
17. Saline and alkali soil/lands,
18. Boundaries and sides of play grounds,
19. Residential areas: between houses,

20. Water logged and marshy areas,
21. Abandoned mining areas,
22. Abandoned quarry areas,
23. Sloppy and steep hilly areas and
24. Waste land: common term used for any unutilized land (some of the types mentioned above can also be grouped as waste land).

B. Cultivable land

Trees can be profitably planted in agriculture land provided their branches are pruned regularly to keep the tree growing straight up without shading the crop plants. Following are the possible location for planting trees on cropping lands.

1. Boundaries of properties: trees can be planted closely to form a fence,
2. Big bunds dividing the property into plots,
3. Sides of irrigation channels,
4. Sides of farm paths or roads,
5. Sides of threshing floors,
6. Upper and lower sides of terraces,
7. Other contour structures: bunds, walls, trenches,
8. Small pockets or uncultivable areas in a cultivated land,
9. Immediate surroundings of farm houses: animal sheds, pump house, Store house, watch man's house, resting place, implement shed, etc.,
10. In cultivated fields: trees can be planted in rows of east-west direction with a line to line distance of minimum 15-20 meters and any convenient distance between rows and between trees to trees in the same row. By pruning

and thinning a clear air space of 5-6 meters would be enough to grow seasonal crops. Such plantations are called farm forestry which may be intercultural or block plantation.

Shading is a major objection for planting trees in the cultivated land. This can be easily solved by timely lopping of side branches during crop season and training the trees to grow straight. Such trees will have high timber and other economic value. Pruning branches early will enhance the growth of the trunk of the tree straight and long.

WHAT TO PLANT?

What type of trees should be planted in forestry depends, mainly on the needs of the people of the area, especially the needs for fuel, fodder, green manure, oil seeds, fruits and small timber etc. However, needs cannot be the sole criterion for selection. One has to consider soil and climatic conditions too. In areas where soil erosion is a problem, trees are planted mainly for controlling soil erosion. Any type of 'trees do not grow in saline-alkali soils. In areas, which are very dry and have acute water scarcity, trees that are drought resistant, fast growing with succulent stems, leaves and profuse summer foliage should be incorporated in the plantation at the initial stage. These trees can reduce the intensity of summer heat by giving partial shading. Their leaves and tender branches can be used for mulching and for supplying the much needed moisture to the plants. Thus, one has to strike a balance between what is really needed and what is really possible. The decision should be made with the participation of people. In the full participatory process of decision making, people need to be guided in the proper selection of species according to soil and climate and their needs. Choice is limited under certain soil situations. Table-1 provides a list of trees that

can be grown in different problem soils. The names of trees given are only examples and they can be replaced with any locally available or exotic trees of similar characteristics or suitability.

Table 1: Species suitable to problem soils

Sl. No	Type soil or land	Species of trees/plants*
1	Water logged (including areas which are always moist or swampy)	Safed siris (*Albizzia procera*). Dhak (*Butea monosperma*), Jamun (*Syzygium cuminl*), Baisi (*Salix tetra sperma*), Arjun (*Terminalia arjuna*), Eucalyptus sp. etc.
2	Stream banks, canals, drainages, seasonal	Safed siris, arjun, baisi, shisham (*Dalbergia sissoo*), Casuarina, etc.
3	Low lying portions subject to prolonged inundation would be generally unfit for tree planting. Such areas are good for mangroves	Babul (*Acacia nilotica*), Kalasiris (*Albizzia lebbeck*) safed siris, dhak, jamun, etc.
4	High banks of any water bodies or ways,	Babul, Casuarina, Agave sw., siris, Neem, losora (*Cordia dichoma*), Parkinsonia, aculea, Vilayati babul (*Prosopis spp*), ber, (*Ziziphus spp.*) et
5	Ravines, deep gully areas	Babul, Agave sW' siris, Neem, lasora, shisham, sanatta (*Dodonea viscosa*) *Parkinsonia aculeae*, Vilayati babul, etc.
6	Rocky, barren lands	Mahua, siris, Deem, sanatta, papra (*Gardenia latifolia*), *Vilayati babul*, ber, etc.
7	Sandy soil areas	Babul, Agave spp., Kala siris, Deem, Shisham, shiwali, jhau, vilayati babul etc., Parkin sonia aculeata, etc.
8	Clayey areas	Babul, ahak, jamun, arjun, asna (*Terminalia alata*), etc.
9	Usar PH 8 to 9 and 9-11 (with soil amendment)	Albizzia, Deem, mahua, Vilayati babul, arjun, kala, siris, safed siris, dhak, Karanj, (*Pongamia pinnata*), etc.

* The species of trees given in column Number three are only examples from the Hindi Regions of our country. Depending on the areas or types soils and situations selection of trees from local areas could be done and their names could replace the names given in the table1 column No.3.

PLANNING FOR PLANTATION

Tree plantation is a long term project and proper planning is a very important exercise. Following components are included in the planning process.

1. Estimate the total area of plantation,
2. Decide what type of fuel, fodder, timber, fruit, oil seeds, manures, shading, ornamental, soil and water conservation are desired,
3. Decide the species of trees under each type,
4. Decide the type of planting: monoculture, randomly mixed, line plantation, strip or block plantation, integrated plantation, etc.,
5. Decide the design of planting: square, rectangular, quincunx, hexagonal or in contour lines,
6. Estimate the species of trees and the number of trees under each species taking into consideration mortality in the field (generally, 15 per cent),
7. Order/buy the required kind or number of saplings or seedlings from a reliable nursery or raise them in your own nursery taking into consideration the percentage of germination, mortality of seedlings in the nursery, etc.,
8. Estimate the type of fencing or protection from wild or domestic animals,
9. Estimate the size and direction of wind breaks,

10. Estimate what type of soil and water conservation and drainage structures are required,
11. Estimate on the type of irrigation structures,
12. Estimate on the type of implements and tool,
13. Estimate whether any building, sheds, etc. are required,
14. Estimate whether a permanent watch and ward is to be arranged,
15. See the possibility of intercrops and animals rearing prior or during plantation which will provide additional income and also much valuable animal dung for manuering,
16. Foresee all possible problems and adopt counter measures,
17. Make an estimate of the cost and benefit,
18. Arrange for finance to meet the cost,
19. Organize the operations and the labour,
20. Maintain records and accounts,
21. Any other points…….

TREEPLANTING PROCEDURES

There is a distinction between forestry plantation and orchard plantation. For forestry and timber plantation seedlings are better while orchards for fruit production budded or grafted saplings are better. Commercial nurseries give more importance to their profit than the quality of the planting materials and their end results like timber and fruits. Therefore for better seedlings and saplings raised in one's own nursery are better. For this collect healthy and fresh seeds from reliable sources. The procedures of seed collection, selection, preservation and germination of various trees are though similar may differ a little bit from

species to species. A simple and most common practice of separating good and viable seeds from the unviable seeds is to soak them in water; all the seeds that are floating should be discarded. Soak the seeds for twenty four hours and them bundle them in a cloth and keep it in a dark and cool area with a small weight over the bundle to exert pressure to facilitate germination. The soaked seeds can be sown in the **germination beds** also to get the seeds germinated. In three to seven days the seeds will germinate. Those that germinate early and are healthy looking are selected and are planted into well prepared and manured **seedling-beds** and are carefully raised to about four to five leaf stage. Rigorous selection is applied at every stage; select only the healthy and fast growing seedlings; select only 50% of the best of the seedlings and transfer them into bigger and strong polythene bags and are kept in the **growing beds**. They are well manured, watered and protected from any pests or diseases. Apply vigorous selection of seedlings throughout the one year of nursery period both for forestry plantation and fruit trees plantation in separate nursery beds.

See that the seedlings for the forestry plantation are grown up to one meter high and are healthy looking with a vigorous growth tendency; transplant them into the already prepared and manuered pits prepared one year ahead. However in areas inaccessible to human beings aerial sowing of seeds may be practiced. In that case higher rate of seeds are sown just before the rainy season and wait for the nature to care for the seedlings growing in the wild.

The seedlings raised for orchard/fruit trees plantation are grafted or budded when they are one year old; for budding and grafting one has to learn the techniques or get the help of the experts from professional nursery growers. The grafted and budded seedlings or saplings are looked

after well at least for another year. Still the best of the nursery raising will give only sixty to seventy percent successes in the nursery rising of plants. Keep only the vigorously growing budded or grafted shoots and mercilessly discard the rest. Planting poor quality grafted or budded saplings for orchard growing will become a life-long liability to the owner.

A. Estimation of Seeds/Seedlings

On the basis of the following factors, the number of seedlings or saplings required can be estimated. The factors are: 1. Area of plantation, 2. Plant to plant distance in a row, 3. Row to row distance, 4. Design of planting, 5. Expected mortality (percentage) during the first year the seedlings may be raised in one's own nursery or purchased from a reliable nursery. There will always be mortality of the planted seedlings or saplings which is generally expected to be within 10 percent; hence we should plan for additional planting materials for gap filling at the end of the first year and even at the end of second year.

In general, saplings or seedlings of both forestry and orchard plantation are planted at the beginning of the rainy season. If the place happens to be in a region where rain is plentiful, planting should be done two weeks to one month before the start of rains (pre-monsoon time). But when the rainy season is short, planting is better done right at the beginning of the showers. Thus, trees benefit from the seasonal rains. Planting should not be done during the dry season as heavy watering would be required. It is better to plant on cloudy days and in the late afternoons so that at least for one night duration for the plants get to adjust to the shock of transplantation.

B. Types of plantation

The following are some of the types of planting commonly practiced.

1. Mono culture or single species plantation: planting one type of trees or species, fruits or non-fruits,

2. Mixed plantation: Planting different kinds of plants of trees together. Mixed Plantations are of various kinds which are given below.

a. Randomly mixed: planting together all kinds of trees for various purposes without minding the spacing requirement or species differences,

b. Line plantation: same or different types of trees are planted in separate lines,

c. Block or strip planting: Different kinds of trees are planted on the same land but in different block or strips, for example fuel wood trees and fodder trees. In each block, same species may be planted; this is also called mono-culture,

d. Integrated planting: they are of different types:

i. Integrating narrow spaced trees between wider spaced trees. For example guava in mango, citrus trees among litchi or jack fruit trees. In the integrated planting design large growing fruit trees are planted at a distance of 33 ft or 10 meter square. That means in one acre 40 or in one hectare 100 trees can be planted. Since they take several years to grow and mature we can plant medium sized trees between two trees in every line. They require a spacing of 16 ft or 5 meters. Further in between a third type of crop may be plated which requires 8ft or 2.5 meters spacing. It will be a three tier cropping. Further in the same plot several seasonal crops can be planted. Thus in a well planned multiple or multitier cropping three to four crops

can be planted as subsidiary crops. By the time the primary plantation grows and fills up the space we can have a few years of income from the subsidiary crops though some of the subsidiary crops could be perennial.

ii. Integrating high canopy trees with low canopy plants, eg. citrus trees with coconut trees, with date palms, pineapple with papaya etc.

iii. Integrating short duration trees with long duration trees, eg. Fire wood trees with fruit trees, papaya with or/ and mango, litchi or jamun.

iv. Depending on the climate, moisture availability, type of soil, climatic conditions, possible economic benefit and above all depending on the ingenuity of the planner/ people the cropping designs will vary.

Choice of the type of planting methods depends on the purpose of planting. For commercial purposes, monoculture and block planting are more appropriate. For a social forestry plantation, integrated planting may be adopted. Compared to monoculture and block planting, integrated planting may be labour intensive and hence more expensive in maintenance if the cost of manual labour is also taken into account.

In fruit trees plantation, integrated planting of other trees or intercropping is highly recommended. Integrated planting is more suitable to meet the short, medium and long term demands of the people. Fodder and fuel are short term demands; manure and small timber are medium term demands and large timber is a long term demand. These are met by the integrated planting of trees of short, medium and long duration. The terms short, medium and long terms are relative. In most of the orchard or fruit trees plantation teak trees can be maintained since they can be pruned to grow

straight up to give a long and thick log after twenty to thirty years.

C. Preparation of planting area

Planting site is cleared of all the wild vegetation. This helps in surveying the land and assessing its resources: strong and weak points. It is advisable not to burn anything for clearing a land area. Introduce some animals which can eat up most of the vegetation; those vegetation which are not edible to domestic animals are composted along with the animals dung. The compost will be very useful to manure the pits which will be dug for the plantation.

If it is a high rainfall area with runoff water establish suitable soil and water conservation measures wherever they are possible. Construct nonpermeable water holding structure to collect and store the runoff water. Use a strong and large enough polythene sheet for making the dugout ponds nonpermeable to water. If needed and possible permanent nonpermeable tanks can be constructed both for water collection and fish rearing and watering the animals. Thus one can think of a multiple use of the land area marked for plantation.

Very large planting area should be divided into blocks inter linked by roads and paths laid out in such a way that every plot is accessible by vehicle and every tree is accessible for all types of post-planting care. If needed, set up irrigation facilities. Where such facilities are not possible, establish rain water storage and distribution structures.

If needed the area should be suitably fenced and secured from wild animals and bush fires. If intercrops are planned, the land should be ploughed and soil prepared according to the crops sown. In saline-alkaline soil, facilities for leaching salts down the root zone are recommended.

If the land is sloping plant the trees in contour lines except in very plain land. Demarcate spots for planting every tree, preferably with different types of pegs according to spacing required for various types of trees. Different trees have different canopy size and hence the distance between trees is adjusted to the canopy size. However trees which are pruned and trained for straight and long wood can be planted closer. Thus all the timber trees can be planted closer than their normal canopy size. Hence marking of the location of planting of saplings or seedlings is done accordingly. Then as the trees grow alternate ones are removed and used as small timber.

D. Water collection structures

As already mentioned wherever there is good rainfall, the surface runoff water should be collected into non-permeable tanks in the plantation area. Conserve and store as much runoff water as possible available at strategic points in the planting area, to be used during the water scarcity periods. The collection structures should be leak free by cementing or spreading strong polythene sheets on the ground and if possible from evapo-transpiration-loss by covering the water area with suitable materials.

E. Composting structures

All the plants require essentially about 17 to 20 elements for their growth and development. The recommended chemical fertilizers provide only two or three elements; the rest of the elements are obtained only through the compost applied once or twice a year. Besides, the compost improves the productivity of the soil. Every cultivated soil should have at least 5 per cent organic matter in the form of well prepared compost. Application of chemical fertilizer will be effective only if a minimum of three kilograms of well

prepared compost is mixed with the soil for every square meter area of soil. In other words every plant should receive three kilograms of well prepared compost per year. At least one year is required to form the compost. Hence while clearing the land itself try to think of compost preparation and set apart location to prepare the compost. All the cleared plant materials should be composted instead of the usual practice of burning them. People justify burning and use of ash as manure; ash provides only the potassium; all the other elements are lost by burning. Whereas, in composting preserves all the elements in the vegetation along with the organic matter which is considered as the soul of the soil.

F. Spacing of trees

A tree requires sufficient space below and above the ground to spread its roots and branches. Spacing varies with the type of trees. Table 2 gives a tentative spacing recommended for various types of trees.

Table 2: Approximate Spacing of some of the trees used in orchard and social forestry

S l . No.	Types of trees	Spacing (meters)
1	Almond	6-8
2	Apricot	6-8
3	Apple	8-9
4	Avocado	8-9
5	a) Banana tall varieties b) Banana dwarf varieties	2.7 m x 3.0 m 1.8 m x 1.8 . m
6	Ber	11-12
7	Bread fruit	11-12
8	Cashew nut	7-8
9	Cherry	9-12
10	Custard apple	5-6

11	Date palm	11-12
12	Fig	3
13	Grape fruit	6-8
14	Guava	6-8
15	Hazelnut	2-3
16	Jackfruit	10-12
17	Jamun	10-12
18	Japanese persimmon	7-8
19	Kagzi lime	5-6
20	Karonda	1-2
21	Lemon	5-6
22	Litchi	10-12
23	Loquat	7-9
24	Mandarin	5-6
25	Mango	10-12
26	Mangosteen	10-12
27	Mulberry	6-8
28	Papaya	3-4
29	Peach	6-8
30	Pear	4-5
31	Pecan nut	10-12
32	Phalsa	5-6
33	Pineapple	1-2
34	Plum	5-6
35	Pomegranate	5-6
36	Pumelo	5-8
37	Santra	6-8
38	Sapota	8-10
39	Sweet orange	6-8
40	Walnut	10-12

41	Fuel trees	1-2
42	Manure trees	2-4
43	Fodder trees	2-4
44	Small timber trees	1-2
45	Large timber trees a. till 5-8 years b. till 8-15 years c. above 125 years	 1-2 2-4 4-8
46	Bamboo	10-12
47	Coconut, other palm trees	10
48	Aracanut, similar palms	2.7
49	Timber trees	2-3
50	Trees for perennial forest	1-2

NB. Selection of trees should take into consideration of saline and alkaline nature of the soil.

In every leveled land, planting can be done in square, diagonal, quincunx or hexagonal; on slopping land contour system of planting is preferred. Variation in spacing is due to factors such as varieties, soil fertility, availability of moisture, purpose of plantation whether for fruits, seeds, fuel, fodder, manure, small and big timber etc.

Spacing is an important consideration for thinning operation in timber trees if no intercrops are planned. Saplings planted for large timber should be planted initially at closer spacing to maintain an optimum coverage of area. As the plants grow and more space is required, they can be thinned out by removing alternate ones in the rows. By thinning the spacing is doubled. It can be done whenever branches of trees begin to overlap. Generally, the first

thinning is done when trees are five to eight years old, the second when they are about fifteen years and the third after fifteen to twenty years planting. The thinned out trees are used as fuel wood or small timber and the leaves are used for mulching, composting or as fodder. Therefore, while planting saplings for large timber, spacing should be so chosen that, on progressive thinning, it will provide sufficient space for the remaining trees to grow.

G. Marking of pits

The location of each pit is marked according to the design and the distance of plantation. On the slopes plantations are done in contour lines keeping more or less the recommended distance between the row to row and plant to plant distance or at random distance. The places for all the pits are marked with a peg each. Marking of the pits should be done carefully so that space is not wasted. On the leveled ground we can choose any design between square, rectangular or hexagonal. It is good to estimate the approximate number of pits in the given area and also to estimate the labour and material requirement and the estimated cost.

H. Size of the pits

The size of the pits varies with the nature of soil and type of trees. Pits should be bigger and deeper when dug in saline-alkaline compact, stony, infertile and shallow soil. Generally, pit size in good, poor, and very poor (saline-alkali) soil should be 60 x 60 x 60, 90 x 90 x 90 and 120 x 120x 120 cm respectively. As already mentioned the depth of the pits on the slopes should be measured at the lower side of the slope. In waterlogged areas, mounds of 60-90 cm high are made to plant the trees, besides the necessary drainage facilities. In the permanently submerged areas establishing

mangroves with fish culture would be economical and ecological. The bigger and deeper the pits and better their preparation, the greater is the survival rate of saplings planted in poor soil.

I. Digging and weathering of the pits

While digging the pit, care should be taken to place the top soil on one side and the bottom soil on another side. Allow the dugout soil and the pit **to weather for a whole year exposed to seasons and weather conditions of the place**. Any hard pan formation present in the soil should be broken while digging the pits to facilitate easy penetration of roots.

In saline-alkali soil, deeper and bigger pits are made even one year ahead and the salts are leached down by filling them with water periodically through irrigation or rain. They are filled in with and a mixture of good soil transported from outside, farmyard manure and pyrites or gypsum. The quantity of manure and pyrites/gypsum varies with the pH value and the amount to be used for each pit as is given in table 3.

Table 3 Farm yard manure and gypsum/pyrite requirement

Sl. No.	PH Value	Farmyard manure tons/ha	Gypsum/pyrite tons/ha
1	3.0 – 9.0	5	2.0
2	9.0 – 9.5	5	2.5
3	9.5 – 10.5	5	3.0

From these recommendations and from the number of pits per hectare we can estimate the amount of farm yard manure and gypsum/pyrite per pit. Beyond pH 9.5 only very few plants survive. For such areas one should identify

such locally available alkaline tolerant plants, multiply and plant them. If they are not available locally, exotic species may be introduced. When there is problem of termite, BHC or Aldrin powder is mixed with the above mixture at the rate of 50-100 gm per pit. After weathering, fill the pit up to two-third to three-fourth height with a mixture of top soil and well rotten farmyard manure in equal proportion.

J. Time of digging the pits

Digging of pits is a very laborious operation. The hardship increases further if the weather is hot and sunny and the soil is dry and hard. The human efficiency in digging pits during hot summer is considerably low and, hence, highly uneconomical. To reduce this hardship, it is better to dig the pits during the winter season or when the weather is pleasant or cool and the soil has sufficient moisture.

On slopes and ravines, instead of pits, trenches of 60 cm width, 45-75 cm depth and 3.5 meters length are dug in contour lines and the soil is placed on the lower side of the trench in the form of a ridge. Saplings are planted on these ridges at the appropriate spacing. The trenches are adjusted in such a way that they fit in between rows of trees. The same procedure may be adopted in dry and shallow soil areas because digging of pits and heaping of the soil conserve more moisture from the rain and makes it available to the plants.

K. Transport of seedlings/saplings

Healthy and vigorous seedlings or saplings of one year or one meter high and grown in polybags should be transported to the field and should be preserved under a partial shade and in good condition till they are planted out into the fields. Utmost care should be taken not to damage them while transporting. At least 20% extra seedling/saplings

should be stored for making up any loss during transport and also to do the gap filling after one year of plantation. The maximum expected mortality is ten per cent and hence the recommendation to store about twenty per cent extra seedlings or saplings.

L. Partial filling of the pits

After one year of weathering of the pits put back the top soil mixed with farm yard manure at about 1:1 ratio up to three-fourth the height of the pit and leave for few months for weathering.

M. Selection of seedlings

Healthy and vigorous saplings or seedlings can be recognized and distinguished from the poor and unhealthy seedlings. Be rigorous in the selection of the seedlings for planting and discard the poor ones. **Often 40 to 50 of the seedlings are not suitable for planting** or it is useless to plant them as they would remain stunt lifelong. This is especially true in the case of fruit trees. Planting of seedlings in pits should preferably be done on a cloudy day or in the evenings. Plant only the vigorous saplings that are one year old or one meter high. Some of the steps taken during planting into the pits are given below.

1. Dig up a small hole into the soil mixed with farm-yard manure placed into the pit earlier after weathering of the pit; the hole should be big of enough to fit the mud block surrounding the root system and also up to one-third of the plant height from the bottom: one-third to half the height of the seedlings should be below the ground level; that will provide strong and deep root-anchoring for each plant or tree in the future.

2. Remove the polythene bag covering in the mud ball

at the base of the plant in such a way that the mud ball remains intact.

3. Place the mud block of the seedling in the hole in such a way that nearly one third of the bottom length of the seedling along with mud block is fitted into the soil.

4. Hold the seedling straight till the pit is filled. Heap the soil around the stem of the plant and press the soil all around the plant.

5. Care should be taken to compress the soil around the seedling/sapling so that it will stand firm and up right.

6. Gather the soil into a heap from around the seedling so that water does not remain stagnant during the rainy season.

7. If the seedlings are slender and drooping, they should be the given support by planting a stick firmly near and tying the seedling to it.

8. Twenty per cent more seedlings should be stocked in a suitable place and looked after for gap filling at the end of first year or at the beginning of the 2nd year so that at the time of gap filling, seedling will be of the same age.

POST-PLANTING CARE

Post-planting care is extremely important for the survival of plants. Some of the most important Post-planting care operations are enumerated below chronologically.

A. First year

Rainy season

1. After planting the saplings during the early rainy season, immediate care should be taken to prevent water logging in the pits.

2. During the first few months, each plant should be

visited at least once a week and ensure that they are in good condition and growing vigorously.

3. Check on the soil and water conservation structures in the field and see no water is lost and where ever possible runoff water is allowed to sink into the soil or stored up in tanks for watering the plants in the summer. Huge polythene sheets can be used to spread inside big or small excavated ponds to collect the surface runoff water for future use. One can easily identify such runoff water collection locations. If sufficient water is available throughout the year then the owner can go for fisheries and aquaculture programmes to augment his profit. The most important point emphasized here is that if we start collecting the runoff water we will be surprised to see the amount of water that we lose every year by way of run off during the monsoon season.

4. Check on the drainage and see that no water stagnation takes place around the seedlings/saplings.

5. Ward off all animals that may harm the plants.

6. Ensure the plants get established and start growing vigorously.

7. At the end of rainy season make a basin like structures 45-60 cm in diameter around each plant with a heap of soil just around the plant to prevent water stagnation just around the plant. Rain water will be conserved in basin like structure which will be available slowly to the plants conserve water gathered from rain. Mulching with leaves in the basin like structures will preserve the moisture in the root zone of the plants.

8. Weeds growing any are removed by plucking and placing on the basin as mulch. Spread a thin layer of soil over this mulch. This l will preserve the moisture up to summer.

9. Check for any possible diseases and pests.

10. If intercropping is taken, operations carried out for them will be beneficial to the saplings. Inter cropping with one or different types of pulses, vegetables, bananas etc. will be useful and profitable. After the banana crop the chopped stem and other parts of the plant can be used for mulching around the plant and cover them with a thin layer of soil to keep the soil moist for a long time.

11. If there are excess of weeds and pruned branched after sufficient mulching they should be composted to prepare organic manure into which if available mix with animal dung and household wastes.

12. **Every plant should get 3 to 5 kilograms of compost per plant per year** besides any recommended chemical fertilizers. For this in the field or in every plot composting can be done using the weeds and other plant and animal waste materials available. Every plant requires at least 17-20 elements for their growth and development. The chemical fertilizers will mostly provide only two or three macro-elements Rest of the 17 elements though needed in small amount are very essential for the growth and development of any plant. As already mentioned "Organic matter through composting is the soul of the soil", meaning it is the compost that maintains the production capacity of the soil; without organic matter the soil will be like a dead body unable to be productive. Though the organic matter in the soil is the least in amount (around 5 per cent) it is the life of the soil. Hence

Winter

1. If needed, a second weeding is done and use them as mulch.

2. In areas of severe winter, shading should be provid-

ed to the plants to protect them from frost. Light sprinkler irrigation in the evenings will also protect the plants from frost bite.

3. Check for any possible diseases or pests and found any take corrective measures.

4. If intercrops are taken all intercultural operations done will be beneficial for the saplings too.

5. All weeds and crop and weed residues should be recycled into the soil both as mulch or as compost.

Summer

1. Depending on the intensity of summer, facilities for irrigation-should be arranged. Plants should be irrigated once in two or three days or when the symptoms of wilting appear. If needed shading is provided to protect the plant from scorching sun.

2. If water is scarce, practice pot irrigation or sprinkler irrigation. For pot irrigation bury medium sized pots, about 15 cm close to each plant on the upper side of the slope, fill it with water and cover it to reduce evaporation to the minimum. With pot irrigation filling of the pots may be done only once in 10-14 days. Sprinkler irrigation requires a high level of technical help and is costly though very effective. Choice of irrigation method depends on the area to be irrigated and the availability of water in the area, labour, topography and type of trees planted. Use good quality water for irrigation.

3. If watering is not possible, provide shading to each plant.

4. Burying green leaves and succulent plant materials close to the plants can provide sufficient moisture to saplings to tide over the summer months.

5. Coating the stems of the plants with white materials like plaster-of-parries or any other white thick solution can protect the plant is from high radiation.

6. Ensure that the saplings survive during the first summer by foreseeing all possible problems and adopting suitable measures to counteract them.

7. Every week check for any possible diseases.

8. In the case of fruit trees, pruning and training could be done if needed; do not allow any branches till about 4-5 feet height to grow on the main stem. Normally branches are allowed only about five to six feet height. In the budded or grafted plant sprouts may appear from the root stock area of the plant; such sprouts should be removed immediately; otherwise the grafted or budded portion will fade away and die in few months. Allow the sprouts only at the grafted portion of the plant and see that no damage is done to the sprouts from the upper portion of the plant.

B. Second year

Rainy season

1. Remove shades if they were used during the previous summer.

2. Level the basin-like structures; leave a heap of soil to prevent water logging just close to the plant. The heap of the soil around the plant can end up at the periphery with a depression forming a ring around the plant to facilitate rain water percolation. Mulching can be practiced to reduce loss of moisture through evapo-transpiration due to scorching sun.

3. Retain the pots at its place if pot irrigation is needed in the second summer.

4. In contour planting, extend basin like structures on

both the sides of plant so that it joins the extended basin of the other tree to form a continuous terrace like platform. The slope of such terrace should be towards the hill side to allow maximum collection of rain and runoff water and allow infiltration of rain water into the soil.

5. Do gap filling if any plant has died during the first year.

6. Remove the weeds and use them as mulch with a layer of soil spread over it.

7. Check on each plant and ensure that it is in good growing condition.

8. Remove any branches developing at the base of the stem.

9. Ward off any predator animals by fencing, if needed.

10. Check soil and water conservation and drainage structures and take appropriate corrective measures, if necessary.

11. Check for possible pests and diseases.

12. If possible, fertilize the crop at the beginning and end of the rainy season. Apply NPK mixture containing nitrogen, phosphorus and potassium (NPK) 100:50:50 g/tree or according to soil test Nitrogen is given in split doses, and others at the beginning of rainy season.

13. If intercropping is taken, operation done for it is enough for the saplings.

14. Remove flowers if any appearing on the grafted plants to encourage vigorous growth; flowering and fruiting at early stage will retard the growth of the plants. Never allow fruiting before five years or till the plants are sufficiently grown and become healthy to bear fruits.

Winter Season

1. Operations will be the same as those of the first winter.

2. Remove any flower shoots appearing on the plant; it is not yet time for the fruit plants to bear fruits before at least five years.

Summer

1. Repeat the same operations as done in the 1st summer.

2. Remove flower shoots if any.

C. Third year

Rainy season

1. If required, complete the gap filling with three-year old ion saplings.

2. Prune the lower branches and train the plants for upward growth. Approximately one-third of the branches can be removed from the lower side of the non-fruit trees to encourage straight upward growth. In the case of fruit trees pruning and training should be started for providing a desired shape and size. The branching should be such that all will receive sunlight abundantly.

3. The pots may be removed if the plants are established and are able to withstand summer. By now, the soil and water conservation structures should be maintained to conserve maximum moisture in the soil.

4. Increase the quantity of manuring and fertilizers (NPK the 150:75:75).

5. The remaining operations may be chosen from the list given at for second year rainy season.

Winter

1. Same as given for the 2nd year winter

2. Pruning may be required for temperate fruit trees.

Summer

1. Trees planted for shading of the seedlings are partially cut back to expose young trees more to the sun. By now, the young trees should have developed sufficient canopy to shade the land and reduce the moisture loss to the minimum. It will also toughen the seedlings to withstand the summer.

D. Fourth year

Rainy season

1. If possible increase manure and fertilizers.

2. Select operations according to the need.

Winter

Select operations according to the need.

Summer

Select operations according to the need.

E. Fifth year

By the time the trees are five years old, they should be fully established in the plantation and uniformly growing. They should have attained proper shape and direction of growth.

From the fifth year onwards, fruit trees may be allowed to flower and fruit if they have attained sufficient vegetative growth. If fruiting is allowed, additional manuring and fertilization should be given to cope up with the requirements of nutrients for further growth and fruiting. Care should be

taken that fruiting does not affect the growth of tree.

For non-fruit trees grown for fuel and timber, prune the lower branches and allow them to grow straight up. They can be harvested from the seventh year onwards depending on the growth of trees and requirement. By fifth year the fodder and green manure trees may be ready for harvesting.

PRUNING AND TRAINING

Fruit trees require pruning and training. Pruning means removal of unwanted, overlapping, poorly growing, diseased, sprouts from the root stock, dried up branches and small braches up to about five to six feet high so that all the branches left over in the fruit tree will grow and fruit well. Training refers shaping of the tree in such a way that all the bearing branches will be exposed to sun light. For various kinds of fruit trees the pruning and training will be different. In certain trees they need hard pruning while some other light pruning and in some no pruning is required. One has to learn the pruning methods for each type of trees. Similarly the time of pruning is also different for different trees. Care should be taken while pruning not to split the branches or stem. Give a slant and clean cut using a well maintained saw. The cut portion may be smeared with coal tar, paint or some other water proofing material. Cutting with knives and axes leaves a number of notches in which water and decaying material cause rotting. The cut portion is a suitable place for worms and insects to enter into the tree. Pruning and harvesting for regeneration should be carried out generally during rest period (winter or before sprouting of new shoot).

Harvesting and grading

Harvesting of fruits from various trees differ from each

other. One has to learn the same for different trees. The fruits may be home use or for marketing. While harvesting fruits, avoid breaking of branches and stripping of leaves. Harvesting of timber or fire wood or small timber trees are normally permitted only from planted forest up to 33.3% slope in loose and erodable soil, and up to 50% slope in firm soils. Above 50% no tree should be harvested except selected trees which should be cut and lifted by helicopters so that no track or heavy machinery routes are made through the forests. The same may be true in a lesser way in planted forests up to 50% slope. It is better to include in the plantation plan all the required roads and paths before planting in those areas one wants to maintain a planted forestry for harvesting forest products.

COMMON DAMAGING AGENTS

A general idea of the type of the agents damaging both fruit trees and forest trees are useful for taking anticipatory counteracting measures.

1. Stray animals

Till the trees have grown beyond the reach of cattle, animals should not be allowed inside the plantation. One day's grazing can wipe away many years of growth.

2. Human interference

Allowing thoroughfare through the plantation provides easy access to anti-social elements to commit theft People should bees: educated and motivated to avoid such anti-social practices.

3. Strong wind

In areas, where strong wind prevails, plantation should include wind breaks planted along the boarders or intermittent strips.

4. Parasitic plants

Certain parasitic plants like *Cuscuta reflexa* (dodder) naturally establish on the trees. Grower should watch for them and remove them entirely before any serious damage is done to the trees.

5. Wild animals

In area having the problem of wild animals, effective measures, such as, electric fencing, trap trenches, strong fencing or permanent watch should be arranged.

6. Birds and bats

In fruit plantations, birds and bats can be real pests. Effective measures, such as, scare crows, watch, net cover, thorns, etc should be adopted in such plantations. Fixing thorns on fruit trees effective against bats. Poison baiting and bird traps may be also adopted against birds.

7. Termites

Termites are ubiquitous insects. Mulching and green manuring often encourage infestation of termites in the plantation area. Once they establish themselves in an area it is impossible to get rid of them. They attack the roots and stems of the trees when mulching and manuering materials are exhausted. Sprinkling BHC or Aldrin powder along with mulching and green manuring materials can b prevent the termite attack. Appropriate measures should be adopted to eradicate termites already established.

8. Rats

Rats can be a real menace to trees planted. They gnaw the roots and make burrows in the root zone weakening the tree. Appropriate measures have to be taken to counteract the rat attack. Clean cultivation and frequent movements of

people in the plantation rally area scare off the rats to some extent.

9. Diseases

Diseases vary with the location, species of trees, and weather .condition. They may be fungal, bacterial or caused by nematodes. A grower should get familiar with the common diseases and adopt preventive measures.

10. Insect pests

Insect pests too vary with weather conditions and types of species. A grower should get acquainted with such pests and take appropriate measures.

11. Fire

Fires can be very detrimental to plantation crops. Fire may spread from outside or originate within the plantation. Outside fife .can be prevented by clearing 8 to 10 feet strip around the plantation. Inside fife can be prevented by maintaining the ground surface free of dry litter which should be incorporated into the soil by ploughing of or digging. Another common method of controlling the fire is to adopt controlled burning. However, this results in tremendous loss of biomass which is very essential to enrich the soil and should can be practiced only as a last resort.

MANURING AND FERTILIZATION

Just like any other crops fruit trees requires manuering and fertilization. Fruit trees are standing in the same place for many years and in the first few years time all the plant nutrients in the soil must be exhausted. Hence periodic/ yearly manuering and fertilization should be done regularly. Manure means organic manures like compost made of a

mixture animal dung, kitchen waste, biogas slurry, weeds, prunings and stripping of plants, night soil from septic tanks, crop wastes etc. Fertilizer means the chemical fertilizers. The Section 52, in Chapter 16 have several technical papers on Manures and Fertilizers. The best way to make organic manure is to dump them all in an upward built room like structures with a door like opening which can be kept closed while filling. There should be at least two structures in one location: when one is filled up and left for decomposition which takes about a year the other will be getting filled up. In high rainfall areas these composting structures should have a common roof. The floor of the composting boxes should be hard cemented with a slope to one side ending into an outlet pipe from which the liquid portion of the decomposition which is rich in plant nutrients and which can be used as liquid manure after diluting it four to five times. More details about various types of composting are available from the technical papers under section "52 Manures and Fertilizers" (MFS), in chapter 16 in this book. Similarly the rate of manuering and fertilizing of each fruit tree is given in Section 46: "Fruit Production" (FPS).

The circumference of root spread of any tree is corresponding to the circumference of the spread of the branches. Hence manures and fertilizers should be applied in a ring form corresponding to the circumference of the shoot system of any tree. The width of the ring could be two three feet. Dig up slightly the ring area and apply the recommended fertilizers and manures. Do not use only the fertilizers alone. Apply well composted and prepared manures at the rate of three kilogram per square meter about two weeks before applying the recommended dosages of fertilizers. Details of planting and caring of fruit trees are given under Section 46: "Fruit Production" (FPS) in chapter 16.

There are many more details about fruit tree plantations. Planting and management of each fruit tree is specific and one has to learn at least the basic things about the fruit trees one is going to plant and take care.

There is no manuering and fertilizing of forest trees except at the initial five years to boost up the growth in the initial years. After that no manuering and fertilizing is required or possible.

NB: Planting and management of fruit or forestry trees require at least some knowledge of the following technical papers which are freely available on line ktchandysj@gmail.com

44. Forestry (FS)

01. Social Forestry…….....	002	FS-04
02. Nursery Raising…….....	005	FS-05
03. Forest Situation in India…….	009	FS-01
04. Planting & Management of Trees…..	021	FS-06
05. Agro-forestry…….....	138	FS-02
06. Farm Forestry…….....	257	FS-03
07. Forest Nursery Raising…….....	460	FS-07
08. Eucalyptus Tree Cultivation…….....	467	FS-08
09. Eucalyptus: Utilization…….....	468	FS-09
10. Shisham…….....	473	FS-10
11. Bamboo…….....	480	FS-11
12. Arjun…….....	492	FS-12
13. Poplars…….....	507	FS-13
14. Babul…….....	511	FS-14
15. Sandal Tree…….....	519	FS-15
16. Teak…….....	527	FS-16
17. Safed Siris…….....……	529	FS-17

46. Fruit Trees Cultivation and Production (FPS)

Chapter-15

Use of Agro-chemicals

Use of Chemical Fertilizers

Many people are opposed to the use of agro-chemicals like chemical fertilizers, weedicides, insecticides, bactericides, viricides vermicides and hormones. No doubt there are many cases of adverse effects arising from improper or overuse of these agro-chemicals just like dangers in the over or misuse of allopathic medicines. Chemical fertilizers and pesticides (used as a general term for insect pests and diseases) are the most used agro-chemicals. In the case of fertilizers the actual recommendation is that the nitrogen, phosphorus and pottasic (NPK) fertilizers prescribed for each crop is to be given only if one has applied well composted organic manure at the rate of 1-3 kilograms per square meter area (10-30 tons per hectare per year) at least 15 days before the sowing or planting of the main crop. Organic matter/manure is the soul of the soil which facilitates the proper utilization of whatever chemical fertilizers applied into the soil. At present people are applying chemical fertilizers without applying the recommended organic manure; hence there will always be problems: it is just like taking allopathic medicines without eating enough food. If the organic manures are not well composted they will be eaten by the termites which will settle down into the field and subsequently start attacking the crops and even the fruit and timber trees. Just like there

should be a balance between the consumption of food and allopathic medicines when we are sick so too there should be a balance between the application of chemical fertilizers and organic manures: "Never use chemical fertilizers without applying the organic manures in agriculture."

Organic manures like cattle dung or plant and other animal wastes were the natural fertilizing materials used by humans from ancient times for their traditional crop production. Ever since high yielding varieties of crops were evolved, use of chemical fertilizers became a need. The simple rule is "apply ten to thirty tons of compost per hectare per year and then only apply the NPK fertilizers recommended for each high yielding crop. For local varieties mere application of 10-30 tones compost per hectare is enough. Improper applications of agro-chemicals do result in adverse effects to people, animals, crop plants and environment as a whole. Applying chemical fertilizers alone to the soil is just like a man taking medicine without taking the normal balanced diet. Just like doctors who learn about many aspects of the use of medicines for human diseases, the use of agrochemicals too need proper knowledge and expertise in plant nutrition and treatment of diseases. That is the only way to reduce environmental problems due to over use of agrochemicals. Both compost and chemical fertilizers are providing plant nutrients; but the compost is responsible for maintaining production potential of the soil in the long run.

Too much of allopathic medicines always does harm to people. Similarly, application of excessive amounts of fertilizer leads to the release of harmful greenhouse gases into the atmosphere and the eutrophication of our waterways. Eutrophication means contamination of water bodies with excess chemical fertilizers causing pollution of water which leads to many health problems to people, animals fishes and other aquatic lives. Excessive

growth of aquatic plants in the water ways blocks transport and trade. Excessive use of chemical fertilizers has led to several issues in India and abroad such as serious soil degradation, nitrogen leaching, soil compaction, reduction in soil organic matter, and loss of soil carbon besides the efficacy of chemical fertilizers on crop yield would be decreasing over time. Quoting data from the beginning of the green revolution, a committee observed that decadal growth rate of agriculture has significantly decreased, from 8.37 per cent in 1960-70 to 2.61 per cent during 2000-2010. It is reported that about 292 districts in India account for consumption of 85 per cent of all of the country's fertilizers. Besides, there are discrepancies in the use of fertilizers on the basis of chemical ratios. The current consumption ratio of nitrogen, phosphorus and potassium (NPK) is 6.7:2.4:1 against their desirable ratio of 4:2:1. Concentrations of heavy metals in the agriculture products have increased to a dangerous level in India as several investigations have shown.

According to the Kerala State Organic Farming Policy Report of 2008: "The advent of chemical intensive farming and its prevalence in Kerala for the past 50 years, has resulted in the near stagnant levels of productivity. The farmers are caught in the debt trap owing to the loan taken to meet the high cost of farming, as it demanded more external inputs such as fertilizers, pesticides and water. These led to increasing instances of suicide by farmers. The tragedy is that people now-a-days hardly apply any organic manure at the required rate but increase the application of chemical fertilizers. Travelling through the length and breadth of the country one hardly notice any systematic effort in producing organic manure in the way it should be prepared in sufficient quantity and applied regularly.

Cattle and other types of animal dungs are the major ingredients for making the compost. In many countries cattle dung is also used as fuel. It is estimated about 150 million tons of cattle dung is used as fuel for cooking of which India's share is nearly 50 per cent (75 million tons). Moreover purposeful compost making in the proper sense of the word is hardly seen

anywhere in India. In the North India cattle dung is commonly used as fuel. Whatever cattle dung left over from burning as fuel, is thrown into any open yard subjected to rain and sun for several months before they are taken to the field without any composting process taking place. The uncomposted cattle dung mixed with fodder plant residues become an easy food to the termites which settle down in the field and create havoc to the subsequent crops. People have dropped the idea of compost making mainly due to its cost both in terms of time, labour and expense. Handling of thirty tons of compost per year is a herculean task for a farmer costing huge amount in terms of money and labour. Hence people go for chemical fertilizers which initially show good results but soon the adverse effects begin to appear: soil becomes unproductive. People seldom realize that in the long run the whole nation will have to pay for all these unintentional mistakes. Use of chemical fertilizers without well prepared manures destroys the productivity of the soil: it is just like taking allopathic medicines without consuming enough of normal balanced food.

Use of Pesticides

All types of insecticides, termiticides, viricides, bactericides, herbicides etc. are termed under pesticides. Often it is necessary to use them to repel organisms causing damage to the crops and animals.

In the use of pesticides few important things are to be kept in mind:

1. Ensure the prescribed pesticide is genuine: many pesticides available in the market are not genuine; often they are dangerous concoctions ineffective against pests and diseases.

2. Apply only at the prescribed dosage or concentration: the farmers being illiterate mostly, do not know how to prepare the pesticides in their correct concentration;

3. Use proper protective clothing or covering while one is dealing with pesticides: hardly any farmer uses such protective and preventive measures nor the owner cares for the health of his workers;

4. Proper disposal of the left over things like containers or packages of pesticides: often the farmers just throw them here and there and in and around human habitat causing contamination to air, water, food etc;

5. Ensure proper training in the use of pesticides: often those who use pesticides have no knowledge of the pesticide resulting in either over use or improper use in incorrect concentrations. We all know the adverse effects of improper use of allopathic medicines.

6. There is no enforcement of the correct way of application pesticides or legal proceedings against the violators of the safety rules in the use of pesticides.

7. Agro-chemicals for plant protection are to be used only at the prescribed dosage just like any allopathic medicines used for human beings.

8. Both over and under dosage are harmful in the case of fertilizers and pesticides.

9. Hence sufficient knowledge about plant nutrients and plant/crop pest and diseases is necessary.

10. In the use of agro-chemicals knowledge, training and precautions are required to ensure proper results and to avoid adverse effects.

According to a March-2020 report by an American Environmental Working Group (EWG), nearly 70% of the fresh foodstuff sold in the United States contains residues of toxic pesticides. The Ministry of Agriculture in India conducted a study to trace pesticides and contaminants in samples collected from various outlets across India. The samples included vegetables,

fruits, spices, red chili power, curry leaves, rice, wheat, pulses, tea and milk. Samples were also collected from farms and organic outlets and tested in 25 participant laboratories for pesticides such as organo-chlorine, organo-phosphorous, synthetic pyrethroids, carbamates and herbicides. The results revealed that 18.7 percent of total 20,618 samples contained pesticide residues and 2.6 percent were above Maximum Residue Limits (MRL) prescribed by the Food Safety and Standards Authority of India (FSSAI). About 12.5 percent of samples had high level of non-approved pesticide, which raises question over awareness among India's agrarian community. Due to many reasons and constraints which are mainly economical, farmers are forced to resort unethical means of food production for the market due to spiraling cost of production and high risk of debt traps.

Hardly any farmer has a proper understanding of the number of plant nutrients and how they interact with soil and plants to produce the food products. Some minimum level information on various plant nutrients is given here to facilitate environmental management of the crops and other plants that are cultivated by people.

Plant nutrients

Like human and animals, plants too need the right kind and amount of food for their growth and development. But unlike humans and animals, plants cannot move around to collect their food. They have to synthesize their own food. To synthesize their food, plants require nutrients in addition to light, air, heat and water. Plant nutrients are therefore, defined as the elements required by the plants to synthesize their food and maintain physiological activities related to growth and development. Most of these nutrient elements are taken by the plants from soil and some from the air. These nutrients are called essential elements.

Chemical analysis of a plant body has revealed the presence of some sixty elements. However, all are not essential for plant growth and development. Only seventeen plant nutrients are so far known to be essential for plants. To

decide whether an element is essential or not the following three criteria have been laid down by the scientists.

1. A deficiency of such element makes it impossible for the plant to complete its life cycle, i.e. vegetative and reproductive stages of plant life.

2. The deficiency symptoms of such element are very specific and can be corrected by supplying only that element.

3. The element is directly involved in the nutrition and other physiological processes of the plant, quite apart from its possible effect in correcting some micro-biological or chemical conditions of the soil. Its effect is quite independent and well defined.

For an element to be essential, it must follow at least one or more of the criteria given above. But it should also be kept in mind that some elements are essential for all plants but all elements are not essential for all plants. Although there is no well-defined scale to classify plant nutrients, they are broadly classified as (a) macro nutrients and (b) micro-nutrients.

A. Macro-nutrients

Nutrient elements which are required by the plants relatively in very large amounts are grouped as macronutrients. Nine elements are placed under macro-nutrients, which are again classified into the following groups.

1. Skeleton nutrients

Carbon (C), hydrogen (H) and Oxygen (O) form the major portion of plant body. But they are not a problem for plants since they can easily reach inside the plant through air and water. These elements are the major constituents

of the plant tissues (a group of cells) which provide mechanical strength to plants. They are, therefore, called skeleton elements.

2. Primary nutrients

Primary nutrients are required by the plants in large amount and soils are very often deficient in them. Nitrogen (N), phosphorus (P), and potassium (K) are placed under this group. These nutrient elements are applied in the soil artificially through fertilizers and therefore, they are also called fertilizer elements.

3. Secondary nutrients

In the order of nutritional importance to plants secondary nutrients come next to primary nutrients. Calcium (Ca), magnesium (Mg) and sulphur (S) are grouped under this category.

B. Micro-nutrients

Though essential, the micro-nutrients are required by the plants in very minute amounts or traces. For example, only one spoonful of molybdenum in one hectare is enough to meet the plant need, while several kilograms of nitrogen may not be enough to meet the nutrient need of the plant. Eight elements, namely, iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo), chlorine (Cl) and cobalt (Co) have identified as micronutrients. The knowledge about the functions of each nutrient is an added advantage to the growers in their judicious use of chemical fertilizers.

Functions of Plant Nutrients

1. Carbon, Hydrogen and Oxygen

Carbon, hydrogen and oxygen form the skeleton and

structure of the plant body. They are the major and essential components of almost all the chemical substances found in the plant body.

2. Nitrogen

Nitrogen amounts to 1 to 4% of dry weight of the plant. It is taken up from the soil in the form of nitrate (NO_3) and ammonium (NH_4) and combines with carbohydrates formed by photosynthetic process to form protein. Nitrogen is an integral constituent of protein. Protein is used by the plants as a raw material in the formation of cells and tissues. Protein is also called a body building substance. A good amount of nitrogen supply to the plant is important for the uptake of other nutrient. Excessive nitrogen supply to plant is harmful as it creates excessive vegetative growth at the cost of grain formation. Excessive vegetative growth also makes the crop more susceptible to lodging and pest attack.

3. Phosphorus

Phosphorus accounts for 0.1 to 0.4 % of dry matter in the plant. It plays a key role in the transfer of energy inside the plant. Thus it is essential for photosynthesis and other physiological processes taking place in the plant. It is indispensable for cell division and for the development of tissue which form the growing points of the plants (stem top and root top). Phosphorus also helps in root growth. It is particularly useful for leguminous crops as it increases the activity of nitrogen fixing bacterial living inside the nodules located on roots of legume plants. Phosphorus helps the formation of seeds and fruits, particularly in legumes.

4. Potassium

Potassium forms 1-4% of the dry matter of the plant

and remains dissolved in cell sap inside the plant. The function of potassium is manifold. It activates more than 60 enzymes (Chemical substances which carry out many life governing processes) and plays a vital role in the formation of carbohydrates (sugars) and proteins found in leaves and roots. It imparts vigor and resistance to plants against attack of pests. Some crops such as tomato, cloves, Lucerne, beans, tuber and root crops and oil seed crops are more responsive to potassium than to other nutrients.

5. Calcium

Calcium content of plant dry matter ranges from 0.5 to 3 %. It is essential for root growth and serves as constituent of cell-wall (cover) material. Most soils contain an abundance of available calcium. The aim of calcium application is usually to correct soil acidity rather than to increase the supply of calcium as a plant nutrient. Application of calcium in acid soils increases availability of other nutrients such as phosphorus, nitrogen and molybdenum. Excess of calcium in calcareous soils decreases the uptake of potassium and magnesium.

6. Magnesium

Nearly 15-20% of the magnesium contained in the plant is located in the green parts and is the central constituent of chlorophyll (the green pigment of the leaves), which carries out photosynthesis process in the presence of sunlight. Magnesium is also needed in enzymatic reactions related to the energy transfer of the plant. It maintains the dark-green colour of leaves and enhances the uptake of other materials particularly nitrogen and phosphorus. It plays an important role in the movement of phosphorus and formation of oil and fat.

7. Sulphur

Sulphur is also an essential constituent of many types of protein. It helps in the formation of fats and oils and accelerates root growth. In legumes, activity of rhizobium (nitrogen supplying bacteria) is increased by sulphur application. Oil contents are also found to increase in oilseed crops if sulphur is supplied to the plants in optimum amount.

8. Micronutrients

Most of the micronutrients are either constituents or activators of enzymes. Enzymes are very important substances which carry out numerous physiological processes inside the plant. Iron and manganese, although are not constituent of chlorophyll, help in the formation of enzymes. Molybdenum and cobalt, in the same way, affect nodule formation in leguminous crops. Other micronutrients also influence several vital processes taking place in the plant.

Deficiency Symptoms

It is difficult to identify the deficiency enzymes of a particular type of plant nutrient because the symptoms created by two elements or more can be very similar. Yet the knowledge of deficiency symptoms of individual nutrient coupled with knowledge of soil factors and the experience of farmer himself can provide greater accuracy in identifying a deficient nutrient. These symptoms can be studied nutrient wise as follows.

1. Carbon, Hydrogen & Oxygen

Plants seldom face the scarcity of these three elements, viz., carbon, hydrogen and oxygen, as they are available from air and water. However, oxygen can be deficient if the moisture is excessive and the soil very compact. Oxygen deficiency results in extremely stunted plant growth.

a. Nitrogen

Deficiency symptoms of the of nitrogen are following

1. Plants go light-green to yellowish in colour, the lower leaves turn yellow and in some cases they quickly start drying up as if suffering from shortage of water.

2. The growth is stunted and stems are dwarfed.

3. In cereals, tilling is restricted and stem becomes spindle shaped.

4. In potato, at the later stages of growth, the margins of lower leaflets loose their green colour and become pale-yellow.

5. In cotton the leaf size is reduced, colour change to yellow or brown and die. Plants produce fewer lateral branches, especially the fruiting branches.

6. In citrus, the leaf shedding is heavy. Leaves become thin, small, fragile and light in colour.

7. In deciduous fruit trees, mature leaves are discolored from base to tip. Under prolonged deficiency, twigs become hard but thinner.

8. In vegetables, there is retarded growth with leaf chlorosis (disappearance of green pigment chlorophyll of leaves). The branches are slender, fibrous and hard.

3. Phosphorus

The deficiency symptoms of phosphorus are the following.

1. Generally, the plant appears dark green in colour but lower leaves may turn yellow and dry up.

2. In corn/maize, leaves and stems show a tendency to become purplish; young plants become stunt and dark green in colour.

3. Wheat, barley and rice have dark green colour, often showing purplish tinge on leaves, often showing purplish tinge on leaves, and retarded growth.

4. In Potato, at the early stages, plants have stunted and spindly growth. The tubers have rusty frown lesions in the form of isolated flecks.

5. The cotton plants have dark green colour, leaves and stems are small and the bolls mature late.

6. Small leaves of legumes are curled upwards. The plants are stunted and spindly.

7. In citrus the growth is reduced. The older leaves loose their deep green colour and lusture and develop faded green or bronze colour. Dead spots appear on the leaves and expand further.

8. In vegetables although, the growth is retarded, the leaves do not show the symptoms of chlorosis.

9. In deciduous fruit trees, young leaves develops reddish purple colour and the new twigs are slender.

10. In many crops, the lower surface of leaves develops reddish purple colour. The stem becomes slender and hard. They bear small dark green leaves.

4. Potassium

The deficiency symptoms of potassium are the following.

1. The margins of leaves turn brownish and dry up, stem remains slender.

2. In tobacco, small spots of dead tissues appear between the veins and at leaf tips and margins which are tucked or cupped up.

3. In maize, at the young stage, the edges and tips

become dry and appear scorched or fired. At a later stage in well grown plants the leaves are streaked with yellow and yellowish green colour and the margins dry up and get scorched. Similar symptoms are shown by oat, wheat and barley.

4. In potato, plant growth is retarded, the leaf size is reduced, leaves become crinkled and curl downward. The older leaves become yellowish and develop a bronze colour at the tips which advances towards the leaf base and die.

5. In cotton, collar rot occurs. First the leaves show yellowish green, and subsequently yellowish spots appear between the veins. The center of these spots dies and numerous brown specks occur at the top, around the margin and between the veins. The leaf curls downwards before it becomes reddish brown and dries up.

6. Yellow mottling around the edges of leaves takes place in legumes. These areas soon dry up and die.

7. In citrus, excessive leaf shedding takes place at blossom stage. Young shoots shed before they become hardened.

8. In deciduous trees, necrosis occurs on leaves. The necrotic area very in size from very small dots patches. Leaves, especially of peach become crinkled.

9. In vegetable crops in the older leaves bronze and yellowish brown colours are manifested near the margins. Specks develop along the veins of the leaves. Ultimately the tissues deteriorate and die.

5. Calcium

The deficiency symptoms of Calcium are the following.

1. Generally, the deficiency symptoms of calcium are localized in new leaves and in bud leaves of plants. In severe

cases the bud at the stem top (terminal bud) dies.

2. In tobacco, the young leaves forming the terminal bud first become typically hooked and die back at tips and margins. The stalk finally dies.

3. In maize, the tip of the unfolding leaves secrete a sticky material and the leaf tips stick together when dry.

4. In potato, a light green band appears along the margins of the young leaves of the bud. The leaves often wrinkle.

5. In cotton, the petiole which connects leaf blade with tem, bends and later collapses resulting in leaf shedding.

6. In vegetables, the stems grow thick and woody and the new leaves become chlorotic.

7. In legumes, the nodules developed on roots are small and fewer in number.

8. In citrus the green colour fades along the edges of the leaf and it spreads to areas between veins.

6. Magnesium

The following are the deficiency symptoms of Magnesium

1. Generally, the symptoms first appear on old leaves.

2. In tobacco, the lower leaves are chlorotic but do not show dead spot. The tips and margins of the leaf are turned or cupped upwards.

3. In maize, leaves slim and yellow streak develops between the parallel veins in the leaves. In acute deficiency, these strip-tissues dry up and die.

4. In small cereal, plants are stunted and leaves develop yellow green patches.

5. In potato the affected leaves are brittle.

6. In legumes, chlorosis begins at the tip and margins of the lowermost leaf and progresses between the veins towards the center of the leaf.

7. In cotton, the lower leaves have purplish red colour with green veins.

8. In citrus trees, the fading of green colour from areas parallel to the midrib occurs and spreads from there. Base of the leaf usually remains green.

8. In fruit trees leaf shedding and necroses occurs as fawn coloured patches on most mature, large leaves. The affected leaves drop.

7. Sulphur

The deficiency symptoms of sulphur are the following.

1. Chlorosis in the young leaves of plants takes place.

2. In tobacco, whole leaf becomes light green in colour though the terminal bud remains alive.

3. Chlorosis in potato develops slowly and the growth of plant is materially checked.

4. Cotton plants dwarf but young leaves do not show colour change.

5. Leaves of vegetable crops become yellowish green, thick and firm. The stems harden and some times and become abnormally elongated and spindle shaped.

6. In legumes the younger leaves become pale green to yellow.

8. Boron

The deficiency symptoms of Boron are the following.

1. In wheat, minute chlorotic specks appear on older

leaves, which later give an orange tint and enlarge to form irregular areas of bright orange yellow spots in midleaves.

2. In barley inter-venal chlorosis takes place when the plants is about 7 weeks old. Older leaves develop dark brown necrotic spots along with tips and margins. Eventually the necrosis spreads.

3. Five to six week old plants of maize develop white spots on leaf blade; size of the spots increases to form large irregular necrotic lesions. The growth of terminal leaves is often reduced, they become chlorotic, fail to unroll and exude some soluble salt. No cobs are formed under sevear deficiency.

4. In paddy, small white necrotic streaks develop on the youngest leaves and enlarge to form white irregular patches. Leaves often fail to unroll.

5. Mustard leaves become thick and leathery with purple pigmentation and deformation of younger ones. Terminal bud dies flower buds fail to open and plants do not produce oil seeds.

6. In groundnut the number and the size of leaves are reduced and shoot growth is suppressed. The dry weight of the plant is reduced by 55-75 per cent. Roots turn brown and brittle.

7. Cucumber shows dark green colour of leaves in the beginning which later turns dirty-brown-yellow and chlorotic. Leaves are malformed and leathery.

9. Copper

The deficiency symptoms of copper are the following.

1. In wheat, leaves remain unrolled with the tips severely chlorotic. Chlorosis starts from the leaf tip and progresses towards the base. Plants show bluish green appearances.

In severe deficiency, tips dry and become papery, withered and twisted. Plant remains bushy and no flowering occurs.

2. In tomato leaves curl and old leaves become flaccid and drop. Entire plant shows wilted appearance. Young leaves do not enlarge, go pale and necrotic. Plant develops very poorly with less branches. Root growth is checked. Flowering and fruiting is severely restricted.

3. In guar, necrotic spots develop on leaves and the leaves curl and the plant is affected severely.

4. In cotton, the leaves turn yellowish green with white spots. The upper portion of the plant is affected the most though the veins remain green.

5. In mango, leaves dry out occasionally. They are bigger than the normal size.

10. Iron

The deficiency symptoms of Iron are the following.

1. In wheat, green colour of leaves deteriorates. Symptoms appear first on young leaves. Mild to Strong chlorosis on intravenous areas of barley leaves takes place. The severely affected plant ceases to grow and collapses.

2. In maize, young leaves develop severe chlorosis within 3-4 weeks of sowing. The leaves may totally bleach.

3. In paddy, chlorosis of young leaves is followed by scorching and drying up of leaf tips.

4. In grain crops, root development is suppressed. Chlorosis occurs but veins and petiole remain green. Younger leaves are more susceptible to deficiency. Fruit setting is very poor and flowers shed before fruiting.

11. Manganese

The deficiency symptoms of Manganese are the following.

1. Leaves side buds become chlorotic though the terminal buds remain alive.

2. In tobacco, the young chlorotic leaves develop dead tissues scattered over the leaf. Veins remain green.

3. In oats grey speck diseases has been found associated wit h manganese deficiency.

4. In potato, numerous small brown patches develop which eventually become more extensive.

5. in cotton, bud leaves become yellowish-grey while veins remain green terminal bud alive.

6. In cereals the leaves turn brown or transparent.

12. Molybdenum

The deficiency symptoms of molybdenum are the following.

1. Wheat leaves develop chlorosis along margins and the chlorotic areas turn dry and necrotic. Such symptoms come first on young leaves.

2. Barley leaves also go pale and chlorotic. Leaves twist and form spirals and may be bleached completely.

3. In tomato, symptoms first appear as intervenal chlorosis along the margins of older leaves. The chlorosis later spreads into intervenal areas which become brittle. In severe cases, plants fail to flower and fruit.

4. Extreme deficiency of zinc manifests in chlorotic conditions and in more dark coloured veins of leaves.

5. In vegetable crops, the new leaves have mottled

appearance with yellow colour. In acute cases, the necrotic or dead areas are found on new leaves.

6. In rice *"kharira"* disease occurs due to zinc deficiency which is marked by brown rusty spots on the leaves.

Plant Nutrient Cycle

Nutrients are added or removed from the soil in a continuous process.

Addition of nutrients

Nutrients come to the soil basically through two ways: (a) natural means, such as rain, weathering of parent material, fixation of atmospheric nitrogen in soil and plant by micro-organism, and (b) artificial means which involve the application of fertilizers, organic manures like cattle during and urine, compost, bio-fertilizers and soil amendments like gypsum, sulphur and pesticides.

Removal of nutrients

The major factors, which account for the removal of nutrients from the soil, are (i) crop harvest, (ii) weeds (iii) soil erosion, (iv) gaseous forms and (v) leaching.

1. Crop harvest

The main nutrient loss from the soil is caused by the crop harvest. The average amount of nitrogen, phosphorus, potassium, calcium, magnesium and sulphur removed from the soil by certain important crops is given in Table 1.

Table 1 Average Removal of Plant Nutrients by certain Crops

Sl. No.	Types of Crops Experim-ented	Econo-mic Yield (Qt/ha)	Total Removal of Nutrients (Kg / hectare)					
			Nitro-gen	Phosp-horus	Pota-ssium	Cal-cium	Magne-sium	Sul-phur
1.	Rice	30	84	14	89	21	9	9
2	Wheat	30	125	22	92	16	14	14
3	Sugarcane	880	180	26	270	132	--	25
4.	Onion	370	133	22	177	16	18	34
5.	Tomato	410	84	21	185	31	8	28
6.	Soya bean	25	125	43	101	35	19	22
7.	Groundnut	20	170	30	110	39	20	15
8.	Mustard	15	83	17	71	63	13	26

2. Weeds

If weeds are allowed to grow, large amounts of nutrients are drained out from the soil since they also like crop plants require all the macro and micro nutrients. Weeds are usually removed from the field and burnt. By this process large quantities of nutrients are lost from the soil. Removal of nutrients by weeds can be avoided by controlling weeds at the seedling stage or by composting and incorporating them into the soil.

3. Soil erosion

Soil erosion also causes huge loss of nutrients from the soil along with the loss of soil itself. It is estimated that about 2.5 million tones of nitrogen, 3.8 million tones of phosphorus and 2.6 million tones of potash are lost annually

from our country by soil erosion (Indian Farming, October 1986). This loss exceeds the amount of indigenously manufactured fertilizers in the year 1981-82. Erosion losses are predominant in agricultural land, soils which are light in texture and in areas where soil and water conservation measures are not adopted.

4. Gaseous form

Loss of nitrogen from the soil also takes place by conversion of fixed form nitrogen in the soil into gaseous form. In gaseous form like ammonia nitrogen is liberated to atmosphere and cannot be utilized by the plant. This conversion may be brought about by micro-organisms (denitrification) if soil aeration is poor, or it may be completely chemical (volatilization) if soil is very saline and alkaline in nature.

5. Leaching

In some light soils of wet regions, nutrients are leached down to the deeper layers and are no more available to the plant roots. The gain and loss of nutrients are affected by a number of factors like soil properties, type of crop and its variety, environmental conditions, etc. The productivity of a soil depends upon the balance between the gains and losses of nutrients. If cropping is continued without supplementing for the nutrient losses by crop harvest soil cannot sustain its productivity for a long time.

Maintenance of plant nutrients

The factors, which contribute to the maintenance of plant nutrients in the soil are: (a) organic manures, (b) fertilizers, (c) soil amendments, (d) soil and water conservation, (e) drainage, (f) crop rotation, and (g) proper soil management practices.

1. Organic manures

Organic manures like farm yard manure, compost, green manure oil cakes sewages, crop wastes etc. must be recycled into the soil for the maintenance of soil fertility. Organic manures release a large amount of plant nutrients when they undergo decomposition. They are the food for millions of useful micro-organisms inhabiting the soil. Unlike fertilizers, organic manures release micronutrients after decomposition. Further they provide a resistance capacity to the soil against excessive build up of any element and are essential for maintaining good soil physical conditions.

2. Fertilizers

Fertilizer application is necessary to sustain higher yields of improved varieties of crops. Sometimes the soil may be already very rich in plant nutrients, but they are not readily available to the plant as they are not in water soluble form. Fertilizers contain plant nutrients in readily available form. They can meet the pace of nutrient requirement by the plant. Yet the recovery of fertilizer nutrients by plants seldom exceeds 15-30 per cent. The remaining portion is either fixed with the soil particles or lost by various ways from the soil. The fixed nutrients may again become available to subsequent crops when there is a stress upon nutrients. To supply micronutrients, micronutrient fertilizers and fertilizer mixtures have been developed but their use is restricted due to cost factors and technical difficulties in use.

3. Soil amendments

The amount and availability of plant nutrients in the soil is very much dependent upon soil reaction. In alkaline soils, availability of some micronutrients goes so low that

plants may show the symptoms of micronutrient deficiency. Likewise in acidic soils most of the phosphorus is converted unto unavailable form and the nitrogen is converted into gaseous form and released into the atmosphere. These types of losses are sometimes, exceedingly high depending upon the agro-climatic conditions. The amendments of these soils are necessary to ensure a good crop production. Material used as amendment of these soils is necessary to ensure a good crop production. Materials used as amendments themselves contain some plant nutrients like lime, sulphur, etc., depending upon the type of amendment. Secondly these amendments have profound impact on the availability of other plant nutrients. Amendments push the soil reaction toward neutral where availability of most of the plant nutrients is just optimum.

4. Soil and water conservation

The most fertile top layer of the soil skimmed off through water and wind is called soil erosion. Erosion causes a great loss of nutrients from the soil but it is seldom noticed by the farmers especially when splash and sheet erosions are active. All attempts should be made to arrest the maximum amount of rainwater at the site of raining itself. Soil should not be allowed to be drained away along with run off water in scanty rainfall areas.

5. Drainage

In places where water logging takes place, aeration to the root zone is hampered or checked. Due to lack of oxygen, nitrogenous compounds (ammonium) of the soil are converted by micro organisms into gaseous form which is no more available to the plant roots. Nitrogen is therefore lost to the atmosphere in large amounts. Proper arrangement of drainage should be made to drain away excess amount of

water so as to ensure good aeration into the soil. Thus the loss of nitrogen from the soil can be prevented and roots can be provided with enough amount of oxygen to carry out the energy generating respiration process.

6. Crop rotation

A proper crop rotation must be followed to maintain soil fertility. Nutrient exhausting crops like sorghum, rice, sugarcane, wheat, jowar, bajra, maize etc. should be followed by nutrient replenishing crops like any of the legumes. Legume crops improve nitrogen content of the soil. Like wise, deep rooted crops should be followed by shallow rooted ones and so on.

7. Management practices

All the agronomic practices must be given due consideration based on the type and condition of the soil. For example, if soil is sandy, all the dose of fertilizers should not be given at one time. Instead it should be given in two or three split doses. Likewise in sandy soil, shallow but frequent irrigations should be given not one time. This way we can reduce the loss of water as well as nutrients from the sandy soil. Soils with low organic matter should receive more and frequent green and other organic manuring. Weeds should not be allowed to exhaust plant nutrients from the soil and whatever weeds grow should be uprooted and composted to make organic manures and recycles them back to the soil. Farmers should follow an integrated nutrient management (INM) as an integral part of the sustainable agriculture which requires the management of resources in a way to fulfill the changing human needs without deteriorating the quality of environment and conserving all natural resources.

Judicious use of agro-chemicals

Agro-chemicals are to be used only at the recommended dosage: neither more nor less. For this one has to study the preparation of the chemicals in the correct dosage; also he should have the proper equipments and protective wears while applying the chemicals; because often the direct contact with applied chemicals is often adverse to humans and animals. For this proper training is necessary for all the farmers who are often the appliers of agro-chemicals. It is just like application of allopathic medicines with specific dosages and recommendations. There is no point in blaming the agro-chemicals for the environmental harm done by the improper or indiscriminate use of them.

The same is applicable to all agro-chemicals like weedicides, insecticides, bactericides, viricides and hormones etc. Just as each allopathic medicine is to be administered at the specific and recommended dosage so too all the agrochemicals are to be applied with precision.

Crop pests and diseases

There are many kinds of pests and diseases affecting the crop plants. Pests are normally caused by insects which are numerous, estimated to be about 10 quintillion (10,000,000,000,000,000,000) individual insects alive in the world. There is no single pesticide effective for all types of pests though there are a few broad spectrum pesticides. All pesticides are dangerous and their use should be minimum and in the prescribed dosage.

There are thousands of diseases affecting the crops; they are classified into bacterial, fungal and viral and the chemicals used against them are specific though classified under bactericides, fungicides and viricides. Many are the specific medicines for each type of organism. Ordinary

farmers cannot distinguish between bacteria, fungus or viruses let alone to select an appropriate control measure against any of them. Often to the ordinary farmers seek the advice of the merchants or dealers of some agro-chemicals against pests and diseases who think of only their profit not the solution to the problems of the farmers. Often it will not be an exaggeration in saying that all our agricultural food products are soaked in chemicals at the deadly poisonous levels. It has been estimated that **3 million cases** of severe acute pesticide poisonings occur each year globally, resulting on an average in 2,20,000 deaths annually, and that 99% of these deaths occur in the developing world due to ignorance, carelessness, willful negligence, purposeful cheating, excessive profit motive.

Government and NGOs Failed Farmers

Can a highly educated person at the graduate or post graduate level treat himself or his relatives of any common disease? "No" is the emphatic answer. The causal organisms of all the human diseases are similar to that of the crop diseases. They may be due to nutritional deficiencies, fungus, bacteria and viruses of which the illiterate farmer has no idea. How can we expect an illiterate farmer to treat his crops affected with various diseases or pests? The irony is that even the farmer himself thinks that he can treat and control the diseases and pests affecting his crops. The same man does not think of treating himself or his children or his own animals; when his animals are sick he calls for a veterinary doctor. Everyone including the farmers in the world is under a mythical illusion: that a farmer can treat his crops of any diseases or pests and they perish in their belief and poison the food products he produces. The local agro-chemical merchants cheat the farmers selling the wrong pesticides and weedicides which when fails to yield the

desired results the poor panicked farmer doubles the dose of the chemicals or apply another equally wrong chemical thinking that he can save his crops. By such practices he not only lose his crops but also goes irredeemable debts. At the same time he is blamed for contaminating the food products while we seldom think of the regular use pesticides in the storage godowns of FCI (Food Corporation of India).

All FCI godowns use different pesticides for different pests and the following steps are prescribed by the Government to avoid the damage due to various stored grain pests including rodents.

All go-downs are constructed on scientific lines to make them rodent proof by having proper height and damp proof by providing pucca floor plinth.

Food grains are stored by adopting proper scientific code of storage practices.

Adequate dunnage materials such as wooden crates, bamboo mats, polythene sheets are used to check migration of moisture from the floor to the food grains.

Fumigation covers, nylon ropes, nets and insecticides for control of stored grain insect pests are provided in all the go-downs.

Prophylactic (spraying of insecticides) and curative treatments (fumigation) are carried out regularly and timely in go-downs for the control of stored grain insect pests.

Effective rat control measures, both in covered go-downs as well as in CAP storage are used.

Food grains in Cover and Plinth (CAP) storage are stored on elevated plinths and wooden crates are used as dunnage material. Stacks are properly covered with

specifically fabricated low-density black polythene water -proof covers and tied with nylon ropes/nets.

Regular periodic inspections of the stocks/go-downs are undertaken by qualified and trained staff and all senior officers. The health of the food-grains is monitored at regular intervals by a system of checks and super checks at different levels.

Checks and balances

Following Checks and Super checks are conducted in the go-downs by FCI to ensure proper preservation of food-grains in the storage.

Fortnightly inspection of stocks on 100% basis by Technical Assistant

Monthly inspection by Manager

Quarterly inspection by Agriculture General Manager

Super Checks by Regional, Zonal and FCI Headquarters' Squads.

The principle of "First in First Out" (FIFO) is followed to the extent possible so as to avoid longer storage of food grains in go-downs.

Only covered rail wagons are used for movement of food grains so as to avoid damage during transit.

Damage Monitoring Cells have been set up at District, Regional and Zonal levels to regularly monitor quality of stocks and reduce damages.

Concluding Remarks

How is that the public is blaming the farmer for the use of pesticides while the grains in the FCI godowns are socked in pesticides every month? No one comes to help the farmer when the grains are left in the field soon

after harvest totally unattended both by government agents and NGOs for months during the harvest season and allow to rotten: glaring contradictions. Further no one blames the FCI go-down people for using pesticides every month whereas the farmer who uses them once or twice in a cropping season is blamed for all the pesticide contamination in the food items. The FCI go-down people use the pesticides within a well-storage conditions ensuring almost 100 per cent effectives whereas the ignorant farmer applies the pesticides totally exposed to all types of weather conditions which reduces the effectiveness even to zero level: INVISIBLE INJUSTICES to the ignorant farmers. The whole country is staffed with block level agriculture officers who are supposed to assist the farmers in their problems especially to protect their crops from diseases and pests: they hardly do any service or rather support the merchants who sell spurious pesticides to the farmers to get their share of their profit: MOST INGENIOUS PARADOX. Under such conditions the farmers can never be blamed for environment degradation and contamination of food items. Just like human disease control is the responsibility of the government and other health centers and hospitals so too the crop disease and pest control should be the responsibility of the agricultural departments and officers appointed at the block and district level.

Policy Changes

Just like flood, drought and other disasters, crop diseases and pests also should be considered as a national disaster and their control and eradication should be the responsibility of the government and not only of the farmers who are incapable of controlling them just like other human and animal diseases. Such policy changes are

to be put in place for the control of the diseases and pests of the crops are necessary for the betterment of environment.

NB: Technical Papers Recommended for further reading from Appendix

Freely Available on Line: mail to ktchandysj@gmail.com

52. Manures and Fertilizers (MFS)

60. Plant Disease Control (PDCS)

61. Plant Pest Control (PPCS)

Chapter 16

Preparation of Organic Manure

Ecologically speaking "All biomass generated on the earth should go back to the soil in the form of organic manure" as part of the organic matter cycle in the nature. Hence all types of plant and animal wastes generated in a farm situation should be composted and put back into the soil at the rate of 1-3 kg per square meter area. The traditional practice of burning all the plant and animal wastes generated in a cropping land thinking that the ash is manure, is the poorest way of using them. First of all ash is more like a chemical fertilizers supplying mainly potash and calcium in very small amounts; whereas when all the plant and animal wastes are composted and added to the soil it provides all the seventeen plant nutrients that should be available from the soil as mentioned in chapter 15. But when we cultivate high yielding crops nutrients like nitrogen, phosphorus and potassium are required more than the local varieties. Hence fertilizers of nitrogen, phosphorus and potassium are applied over and above the compost. Above all the compost provides the much needed organic matter which is 'the soul of the soil'. Also organic matter provides the soil the buffering capacity which mitigates most of the adverse effects of the use of chemical fertilizers. Organic manures are like food for the soil while the chemical fertilizers are like tonics or allopathic medicines to the soil. Regular and systematic composting

is the best way of recycling all the organic matter generated in the cropping field and is a necessity to maintain the productivity of the cultivated soil.

Methods of composting

There are mainly two methods of composting: 1. Anaerobic (composting without air contact) and 2. Aerobic (composting with air contact). Anaerobic composting is better though it takes more time to compost but there will be least loss of plant nutrients. Wormi-composting, another method of composting requires special infrastructure for the maintenance of special earth worms and more labour and hence becomes more costly and less popular. Hence anaerobic composting is promoted to generate enough of organic manure for soil fertility improvement.

Anaerobic decomposition in which all types crop and plant wastes are held in a upward constructed composting structure of long, short or rectangular size with proper arrangement to dump the waste materials section by section and to retrieve the decomposed products may be a better form of composting. More the height of composting structure greater will be the quantity of organic wastes that can be deposited into it for composting. It is better to construct them in pairs so that when one is full and left for decomposition the other can be filled. By the time the second is filled the first may be composted thoroughly and can be emptied and become ready for receiving another turn of composting. The number of composting units depends on how long or how fast one takes to be filled up: If it takes one year to fill one, then two units are needed; If it takes six months to fill then we need three units; thus one can estimate the number of units needed for him; obviously it also depends on also the amount of bio-material one has to decompose. Based on this basic information on

composting structure one can improvise many ways both in the structure and the way of composting.

The decomposed material is taken out, dried and sieved to get fine uniform sized granules of organic manure, making it easy to handle it in the field. The unsieved materials should be placed back into the composting structure for a second term of composting. Well dried compost can be packed and labeled for storage for one's own use and marketing. Composting can be made into a lucrative business.

Composting Structures

There are many types of composting structures prevalent in the world. Section 52 in the appendix on "Manures and Fertilizers" contains several technical papers on composting. One can adopt any of them according to his convenience. They may be heaping up types, pit types and upward built rooms or silo types; they may be single, double or multiple types. The silo types may have facilities to fill from the tops and take out the composted manure at the bottom facilitating a continuous filling from the top and retrieval from the bottom. Space wise the silo types may be advantageous but cost wise and technical requirement wise it will be costly in the initial investment but the maintenance and running expenditure will less.

The material dumped into the composting structures should be chopped into small pieces to facilitate the composting process. A chaff cutter type of machine or hand chopping may be adopted depending on the situation. Never put big chunks of organic materials into the composting structures; smaller the pieces better and faster will the decomposition.

However a general type of composting design is explained as follows. At a convenient location in the farm

or the village build two adjacent rows of composting boxes of at least 6x6x6 feet size separated by a central thick wall which will used as a common path for dumping the organic wastes into any of the boxes. Have a plinth level of at least one foot high for all the boxes. Build suitable steps to climb easily on to the central wall. The outer side of all the boxes will be open partially in the middle from top to bottom, but should be able to close strongly while filing each box with the organic wastes and open to drag out the composted material. Each box should have a small drainage channel ending into an outlet pipe so that the liquid portion of the composting can be collected individually from every box and be utilized as liquid manure after diluting it at least four times. The inner sides of the composting boxes should be lined by noncorrodable tiles or granite slabs. Ordinary cement or brick walls will be corroded in few months time.

In high rainfall areas the whole structure should be high roofed with a lasting roofing material so that between the composting boxes and the roof we can fix small animal units of chickens, ducks, pigeons, rabbits, guinea pigs etc. The droppings are allowed to fall on to the composting material or are collected to use them separately. Periodically spread evenly the dumped materials and compress them moderately with a long handled tool to expel the trapped air in the composting material. When a box is fully filled, top it with soil layer of one or two inches as a cover and leave it for composting for at least one year. The small animal cages may be shifted around depending on which box is being filled.

When the first section is filled up fully, start filling the second, then the third and the forth. Thus filling and taking the manure out will take place in rotation. If needed spray some water on to the composting material to maintain the

optimum moisture for composting. Keep a record of the beginning and end of filling of each section such as date on which filling started and filling completed, how much sieved manure is got from each section etc.

Silo-types

In a silo type of composting structure we can have single, double or multiple type of structures. The composting material is dumped from the top regularly and after an year it begins to yield compost which can be taken out periodically from the bottom. In the silo method there is no need for emptying the silo. It is a continuous method of dumping the waste and retrieving first the digested compost after a period of one year. From then on digested compost can be taken out periodically. The structural details are so adjusted that what is placed on the top will out after one year of duration.

The structural details of multiple silo method of composting are more or less as shown in Fig 1. Each vertical silo is bent like a half "U" and extended into an open channel of several feet the end of which can be closed or opened as needed. The first batch of material dumped will come and rest in the open channel and begins to decompose. Hence this open channel should be raised both sides and kept covered air tight to facilitate anaerobic decomposing. Subsequently dumped materials slowly fill the channel and the silo part eventually till the top building up pressure on the materials in the channel. Hence depending on the height of the silo and the pressure being build up the length of the channel and height of the side walls of channel should be adjusted in length and height wise. The bent and the length of channel is the figure is much lower than the required dimensions.

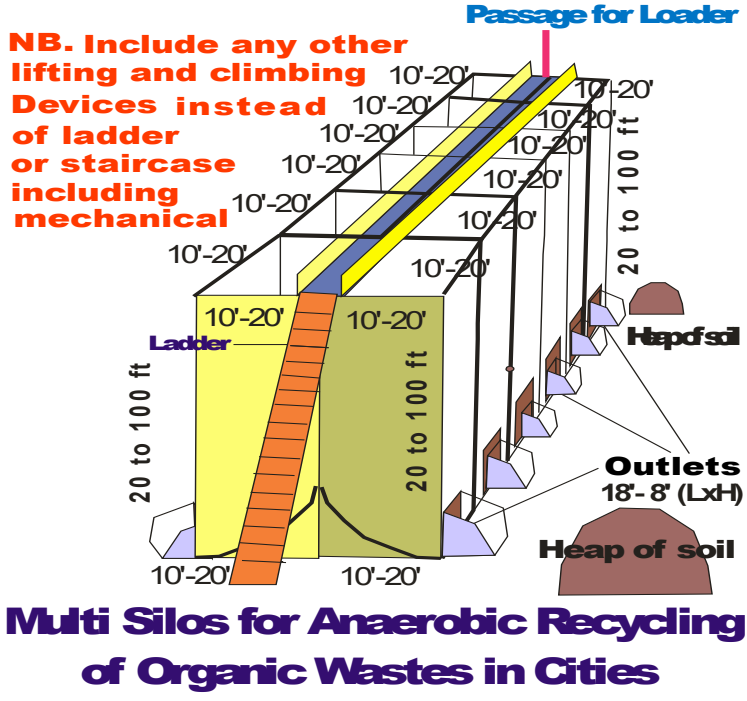


Fig 1. Diagrammatical Representation of Multi-Silo-Method of Composting

The readers can improvise and improve these designs according to their convenience and their own ideas gained from experience. By the silo method all organic materials whether rural or urban can be decomposed; the dried and sieved compost can be stored in packets of convenient size and weight. Composting can be a source of excellent organic manure and a source of income for anyone in the rural or urban areas; above all composting helps in environmental sanitation.

Only organic materials can be composted. Wastes from urban sources need segregation into organic (bio-degradable) and inorganic (non-degradable) materials. Segregation at the source would be the best procedure.

There should be facilities for processing all non-organic materials also. All plastics can be recycled into variety of very useful items; all metal wastes too can be recycled. Similarly all liquid wastes should be also be processed or treated to be used either in agriculture fields or for some other domestic purposes like flushing of toilet or for home gardening as is done in Israel. Treated domestic or urban waste water is a precious resource for agriculture.

In India dealing with waste is attributed to certain lower castes and to the upper castes dealing with wastes is polluting religiously and socially. This is a great hurdle in the way of proper and timely waste management programmes in India. In most part of the country wastes are dumped into the public places like roadsides, common lands, into lakes, rivers, forests, edges of play grounds etc. There is no system of segregating the wastes at the source as in many other developed countries. There is a long way to educate and train the public into proper waste management habits.

Concluding remarks

For a clean environment, all urban and rural wastes, whether liquid and solid, should be processed into organic manure of both liquid and solid types. The non-decomposable wastes like plastics metals, glass wares are also to be processed and recycled into useful products. **"WASTE IS WEALTH"** should be motto of every one in a country. All wastes whether solid or liquid can be converted into many useful products to generate capital and to maintain our environment clean and safe. There are a number of technical papers related to organic manure and waste management in the appendix. They are available free of cost on line.

Chapter 17

(Appendix)

Technical Papers Available Freely On-Line

All over the world maximum harm done to environment is through human intervention for agriculture and animal husbandry. Every year thousands of hectares of forests are destroyed and hilly areas are encroached mainly for agriculture and animal husbandry. Every country should have at least two-third of its area under hundred percent forest cover. Globally the minimum forest cover requirement is 70 per cent. This should include all the areas above 33.3 percent slope which should be under natural perennial forests. But today the world average of forest cover is only 31 per cent; in India it is only 23.83 per cent irrespective of the slope. Rampant deforestation and indiscriminate land use for agriculture and animal husbandry results in massive deforestation and loss of top fertile soil all over the world resulting in ever increasing trend of waste land formation and desertification. In India alone, as already mentioned, the top soil loss is estimated to be 6000 million tons per year; in China it is even more and in USA it is a little more than that of India; the top three agricultural counties in the world. Secondly no agriculture or animal husbandry activity generates any net profit or rather generates prolonged and successive debt traps: hence no farmer is able to follow ecological agriculture and animal husbandry practices. The use and throw away culture is coming into agriculture and

animal sector too. Big corporations lease in huge tracts of land to use for few years and then leave it over exploited. Thirdly those who are involved in agriculture and animal husbandry at the ground level are not educated enough to follow environmentally sound land use: they just follow the age old traditional practices mixed up with age old traditional and mythical ideas. Hardly any farmer learns systematically various ecological aspects of agriculture and animals husbandry nor do they have any source from where they can get the requisite knowledge about environment management. Hence an attempt is made to provide basic resource materials on most of the topics coming under agriculture and animals husbandry in the form of 727 technical papers/booklets. They are available freely on-line on request. A classified list is given below and going through the list any one can choose his requirement.

These technical papers ultimately promote various aspects of Environment & Natural Resource Management (ENRM) for Promoting PEACE MODELS which means Popular Environmental Agronomic Community Education to Mobilize and Organize Environmental Living Systems Which simply means MODELS OR SYSTEMS OF PEACEFUL CO-EXISTENCE WITH NATURE. Just send your requests to ktchandysj@gmail.com for e-copies of the technical papers/booklets mentioned in the list: mention the title of the technical papers/booklet & classification nos.

Subject & Booklet Title	Booklet & Classification Nos.
01. Agricultural Bio-energy (ABES)	
1. Bio-mass Briquetting and Utilization ...375	ABES-4
2. Bio-mass as a Source of Energy …..... 379	ABES-1
3. Fuel from Wastes and Weeds…..... 408	ABES-6
4. Fuel Wood Plantation…..... 575	ABES-5

02. Agricultural Cooperation (ACS)

03. Agricultural Economics (AES)

04. Agricultural Engineering & Technology (AETS)

05. Agriculture Extension & Education (AEES)

10. Agricultural Situation in India (ASIS)

11. Agriculture and Rural Development (ARDS)

19. Animal Husbandry Dogs (DGS)

20. Animal Husbandry Ducks (DKS)

21. Animal Husbandry Goats (GTS)

25. Animal Husbandry: Quail (QLS)

26. Animal Husbandry: Rabbits (RBS)

27. Animal Husbandry: Sheep (SPS)

28. Apiculture/ Beekeeping (APS)

31. Condiments and Spices Production (CSPS)

32. Crop Production Systems (CPSS)

33. Dairy Management & Milk Products (DMMPS)

34. Drainage (DRS)

35. Dryland Agriculture (DLAS)

36. Ecology and Environment (EES)

40. Fisheries & Aquaculture (FACS)

41. Flower Gardening (FGS)

42. Food and Nutrition (FNS)

43. Forage Crop Production (FCPS)

44. Forestry (FS)

45. Fruit Processing (FPRS)

46. Fruit Production (FPS)

47. Health and Nutriton (HNS)

53. Medicinal Plants (MPS)

66. Seed Production Technology (SPTS)

67. Sericulture (SERS)

68. Soil Science (SSS)

69. Soil and Water Conservation (SWCS)

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Dr. K. T. Chandy S. J. had his agricultural and environmental studies up to PhD at Sam Higginbottom University, Allahabad and at G.B. Pant University of Agriculture and Technology, Pantnagar. He worked 25 years at the Indian Social Institute, New Delhi, of which he was Head of the Agriculture and Environmental Education Programme for 10 years. While working at Indian Social Institute he was also the Governing Body Member and Chairman of the Technical Monitoring Committee of AFPRO, Delhi for ten years. In 1994 he participated in a week-long training on "Effective Negotiation Techniques" in Amsterdam. In 1995 he was one of the twelve-member Indian Team selected and invited by the Chinese Government to have a one month hands-on-experience of their Innovative Bio-technological Research Projects. He was the only member from India for the Papua New Guinea World Conference on "Global Forest Situation" in 1996. He was the founder member and teaching staff of two colleges in Nagaland, St. Joseph's College, Jakhama and St. Xavier's College, Jalukie; in the first one he was the Director of Vocational Stream and in the second one he was also the Principal from 2006-08. He also worked as Associate Director of Catholic Health Association of India, Secunderabad from 2008-10. In 2010 he was appointed Professor at Xavier Institute of Management (XIM), Bhubaneswar in the Rural Management Stream, teaching Agriculture and Environment Management and Socio-Economic Analysis. He also worked as a member of the Selection Board and Librarian of the same Institute. In 2012 he was deputed to Mozambique, Africa, to set up a Rural Management Institute. Based on his field level experience in India and abroad he has developed 92 appropriate technologies and developmental paradigms. In 2013 he was back in India and was appointed as Librarian at Vidyajyoti College, Delhi, where he continued his writing of booklets on various topics under agriculture and environment management and 115 case studies in his book on "Invisible Injustices". He has authored so far 12 books besides the 727 technical papers classified under 75 subject divisions in Agricultural, Animal Husbandry and Environmental Sciences. Throughout his active career of 40 years so far, he was in contact with hundreds of Social Activists all over India. Present book on "Fundamentals of Environment Management" is a Magna Carta on Sustainable Environment Management.

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Parayanchery, Kozhikode - 673 016
Ph: +0495 4022600
+91 9746077500, +91 9746440800
E-mail: atmabooks@gmail.com
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